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THE AUSTRALIAN AND NEW ZEALAND JOURNAL OF SURGERY

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WAR WOUNDS AND THEIR TREATMENT.[1]

By HUGH R. G. POATE,

Director of Post-Graduate Surgery, Prince Henry Hospital, Sydney.

THE medical officer of today is in a very much better position in regard to guiding principles in the treatment of war injuries than was the man who left these shores in the early days of the war of 1914-1918.

The only literature available then was the little that was written following the South African campaign, and it was soon found that very few of the experiences gathered then were of any value under the altered conditions of Gallipoli, Palestine and France; in fact, insistence on certain practices, especially in regard to wounds of the chest, abdomen and head and in amputations, was soon found to be erroneous, but not before it had led to the loss of many lives.

Even during the Great War our surgical procedures were in a constant state of flux, and it was not until late in 1917 that any standardization of treatment or technique had become at all general.

In the post-war period investigations and reviews of war-time experiences went on and many new principles were incorporated in the management of accidental wounds in civil practice by the surgeons returning from the war, so that they became routine procedures and as such were a matter of course to the younger generation of surgeons now called upon to play their part in this world war.

Once again the ingenuity of all surgeons is being exercised in dealing with the more severe types of wounds and burns which are brought about by the greater use of enhanced high explosive shells and aerial bombs, with their added risk of gross mutilation as well as severe burns, not only for all branches of the service, but for the civil population as well.

Many surgeons of the Great War have been in the position of teachers to the younger generation, and since those days we have all learned something of the effects of modern warfare from the Spanish Civil War.

We have a better understanding of the bacteriology of wounds and of the value and use of many antiseptics in their treatment, as well as having the help of the sulphonamides in combating both local and systemic infection. In addition we have a clearer knowledge as to both prophylaxis and treatment of the two most deadly wound infections of the Great War—namely, tetanus and gas gangrene—and it seems that the value of tetanus toxoid has been definitely established.

[1] Accepted for publication on December 17, 1941. Read at a meeting of the Royal Australasian College of Surgeons for the State of Queensland on December 5, 1941.

A very complete summary of combined experience and lessons of the Great War exists in two official publications which should be studied by all medical officers of the forces, and which will give them a basic knowledge of the varying conditions they may be called upon to treat. I refer to the two volumes of the British Official History of the War entitled "Medical Services Surgery of the War", which has been compiled by some of the consulting surgeons and surgeon-specialists of the Royal Army Medical Corps and which contains very complete detail regarding wounds of various regions as well as methods of treatment. We also have the "Official History of the Australian Army Medical Services in the War of 1914-1918", edited by Colonel A. G. Butler, D.S.O., V.D., which contains an abundance of interesting and important information for the guidance of military medical officers.

In general, then, one can say that surgeons detailed for duty in the war zone should be fairly well equipped for their work, and particularly so since the responsible authorities, most of whom served with distinction in the Great War, have concerned themselves in training all officers as far as is possible before they leave for overseas service.

The surgery of war wounds is not work for the untrained or occasional surgeon—a fact which has been recognized by the Director of Medical Services, Australian Imperial Force, in a memorandum issued to medical officers in March, 1941, dealing with the immediate treatment of war wounds by those who have had no previous experience in this branch of surgery. The succinct remark is made that "experience will no doubt lead to modification of technique".

As far as I can ascertain from my colleagues serving in the war zone, it seems that three axiomatic principles of the last war have amply proven themselves in the present conflict, namely: (i) The earlier the wounded person can be brought to efficient surgical treatment, the greater the chance of aseptic healing. (ii) The earlier wound shock and blood loss can be combated, the better the chance of survival of the wounded man. And (iii) the earlier a Thomas splint can be applied in cases of fracture of the femur, the greater is the chance of recovery.

The putting of these principles into practice means that the medical services must be pushed as far forward as practicable, must be more widely distributed in smaller groups and must have facilities and necessary equipment for the collection of wounded, their rapid classification as to those requiring immediate attention on the spot, and the clearing of patients suitable for delayed treatment to hospital units further back. Finally, provision must be made for resuscitation teams, including transfusion services, and for these teams to work in advance of as well as alongside competent surgical teams.

THE THOMAS SPLINT.

Before proceeding with any consideration of wound treatment, I should like to refer to the use of the Thomas knee splint and would direct attention to a leading article in *The Medical Journal of Australia*, February 1, 1941, on the subject of its use in civil ambulance work. It should be a matter of surprise to all of us that its general adoption in our civil ambulance services has not been brought about. Perhaps the fault for this lies with ourselves for not having insisted and persisted in inducing ambulance authorities to install the Thomas splint as part of their routine equipment. It was only after steady advocacy of its merits and then the cooperation of the Metropolitan Superintendent of the Central District Ambulance in New South Wales that a modification of this splint was evolved suitable for packing in an ambulance wagon and for the training of ambulance personnel and that it was finally adopted for routine first-aid work.

Even though it has now been in use for many years in the Central District area and is spoken of enthusiastically by the men of this service, it has not been adopted for general use by the ambulance transport service as a whole in New South Wales nor has it been adopted by ambulance services in the rest of the Commonwealth except in Queensland.

The Council of the Royal Australasian College of Surgeons has taken the matter in hand and representations will shortly be made to all civil ambulance bodies in this part of the world to adopt the Thomas splint in their work.

For first-aid purposes the original Thomas knee splint was ideal in its simplicity, ease of application and convenience in transport; yet during the Great War it was not until 1917 that supplies were made available, that a drill was issued for the application of the splint, that medical officers were instructed in its use and that intimation was given that it was to be applied as part of the first-aid treatment in wounds complicated by fracture of the femur.

I understand that during the first two years of the Great War the mortality rate of fractured femurs was about 60% owing to shock, loss of blood and the association of other wounds. Shock was greatly increased during first-aid treatment and transport, but with the general use of the Thomas splint the mortality rate came down to 30%, and it has been stated that this was the greatest single life-saving measure adopted during the war.

That the lesson has not been forgotten is exemplified by the training being received in our militia medical units in which the men are drilled in its application, even blindfolded and in complete darkness out on manœuvres.

In the memorandum of the Director of Medical Services, Australian Imperial Force, already referred to, it is remarked that "cases of fracture of the femur that have been excised and treated on Thomas knee splints with extension, have not travelled well. If orthopædic rests are not available, the Thomas knee splint is, however, the only alternative and must be used."

This followed advice to put all such fractured limbs in a plaster spica. In a letter from one of our surgeons who had a busy time during the Syrian campaign it is stated:

> In these forward jobs we are against plaster for fractured femurs. The application of a plaster spica is time-consuming and shock-producing. They could be made comfortable with Thomas splints and travel in an ambulance better this way. Otherwise we used plaster wherever we could, but not for a humerus, since arm-abduction is almost impossible for ambulance carrying.

Colonel Monro, consulting surgeon to the Mediterranean Expeditionary Force, has suggested that in fractures of the lower limb the use of posterior plaster slabs, with plaster bandage ties incorporating the side bars of a Thomas splint, would give better fixation than the splint used alone.

In some cases in which this method was employed the results were excellent and the method deserves wide adoption (*The Lancet*, June 7, 1941).

It seems that in many cases fractures from Libya did not have efficient fixation and hence the patients travelled badly; but if extension is applied over the unlaced boot there is very little chance of œdema or pressure from the clove hitch. Unless extension or a plaster fixation is applied, the greater part of the value of a Thomas splint is lost.

RESUSCITATION METHODS.

The duty of a resuscitation team is to relieve the surgeon of the necessity for looking after the severely shocked patients requiring special treatment

either before or after operation. The officer in charge of such a team must be expert in the technique of transfusion and should have full charge of the resuscitation ward with an able team of assistants, as upon them rests the responsibility of giving the desperately wounded a chance of life. When citrated blood has to be prepared, advantage must be taken of any slack period to prepare the flasks and store them under satisfactory conditions. The present-day methods of preparing and storing blood and the use of dried plasma and serum have been of inestimable value to resuscitation teams.

In 1917 transfusion as a standard method in the treatment of hæmorrhage had become a routine measure at the casualty clearing stations, and it was then decided to try to save further lives by sending teams up to dressing stations, and Major A. W. Holmes à Court took a leading part in this development. In this war every medical officer should be trained in this work, as it is of the greatest value to the seriously wounded.

During the first campaign in Libya, as well as in Greece, excellent use was made of this service under very varying conditions, and one officer who actually gave some seventy transfusions during the first Libyan campaign, in writing of it, states that undoubtedly the best apparatus is that developed by Lieutenant-Colonel Ian Wood and supplied in the "Transfusion Pannier", its sole drawback in the field, if any distance from the base, being that the "Soluvac" jars could be used only once for blood. Wood has given detail of the apparatus and method in *The Medical Journal of Australia*, June 10, 1939. Whilst this method is recognized as closest to the standard of aseptic perfection, the commanding officer of the Mobile Blood Bank considered it too complicated for the uninitiated, and to overcome this at least one medical officer from each field ambulance attends the central depot for a short course of instruction in its use. It has been found convenient to keep about four pints each of types O4 and A2 in the special ice box always on hand. No preservative is added, but a filter must always be used in the giving of stored blood.

In a large series of transfusions given under desert conditions no trouble was experienced. Use was also made of dried serum for shock without blood loss with most gratifying results. It was found that in the majority of cases it was better to cut down on a vein and tie in a cannula for the transfusion. My correspondent concludes by saying that:

> I am confident if one is thoughtful and careful that the standard transfusion set as devised by Ian Wood is the best thing which has come out as yet and is here to stay.

Of course transfusion is but one means of resuscitation, and provision must be made for the relief of pain, for warmth, rest and fluid nourishment, and, if possible, the resuscitation area must be in as safe a position as practicable so as to relieve the incapacitated from the fear of further injury by bombing.

THE EARLY TREATMENT OF WOUNDS.

The prevention or elimination of infection, either primary or secondary, is the prime consideration in the treatment of all wounds. It has been amply demonstrated that when organisms are implanted into a wound, whether it be superficial or penetrating, they do not tend to invade the surrounding tissues for some eight to twelve hours. This lag period between the time of infliction of a wound and the onset of sepsis is of the greatest value to the surgeons, as excision of the wound with its complete *débridement* often allows of closure by primary suture. The application of antiseptics cannot sterilize the tracks of penetrating or perforating wounds, although they may inhibit infection in open wounds. The only really effective method of securing first

intention healing is by complete excision during the lag period, followed by complete closure without tension and the application of a fixed dressing not to be touched until healing has occurred or sepsis is evident. This applies particularly to cases complicated by fracture when the immediate application of plaster not only seals off the wound from secondary infection, but places the limb at rest and protects it during transport. Trueta during the Spanish war made full use of this method and even went further by covering over wounds which could not be closed by suture. But it must be clearly understood that he laid the greatest stress upon the most thorough *débridement* in all cases before applying plaster.

The wound excision must be carried out with meticulous care by a deft surgeon working under the best aseptic conditions possible. In many cases a complete excision cannot be carried out for anatomical reasons, and it is well to remember that to close an inadequately excised wound is to subject the patient to a very grave risk of sepsis which may imperil his life.

In all cases in which primary suture is contemplated, the removal of any foreign body is of course part of the *débridement*. When patients are received later than ten to twelve hours after being wounded or when satisfactory excision cannot be carried out and frank sepsis has not yet set in, it may be possible to aim at delayed primary suture. The damaged tissues are excised as completely as possible and hæmostasis is effected. The wound is left open and packed lightly with gauze well moistened with flavine solution, 1 in 1,000, or some such efficient antiseptic which will not damage the tissues whilst inhibiting bacterial growth. If the progress is favourable, these wounds may be closed by secondary suture some three or four days later. Incidentally, in such cases the patients stand transport well and can often be evacuated to the base for their subsequent suturing, provided the packing is kept moist during transit.

The main principles, then, in the early treatment of wounds are as follows: (*a*) immediate transport to an operating centre after wounding, (*b*) the treatment of shock or blood loss, (*c*) complete excision or thorough *débridement* of the wound, (*d*) control of hæmorrhage, (*e*) primary or delayed primary suture, (*f*) protection of the wound area and efficient splinting if any fracture is present, and (*g*) rapid evacuation to a safe area.

In regard to the exact technique to be followed it seems to be a question of the experience and training of the individual surgeon as well as of the conditions under which the work has to be done, and again I would remark that such work is for able surgeons alone. The uninitiated should take no risk in the treatment of such cases, especially in the closure of wounds when surgical cleansing and *débridement* have not been carried out in a most thorough fashion.

A loose "Vaseline" pack, with or without local sulphanilamide treatment, is safe and allows of secondary suture at a later date under the more favourable conditions of an organized operating centre or a base hospital, especially if there is any likelihood of delay or a long transport.

In the circular from the Director of Medical Services, Australian Imperial Force, the following extracts are of interest, but I shall not offer any direct comment.

It is recommended, Para. 1, that after excision all wounds be left open and no attempt be made to suture the wound except in cases of G.S.W. of the skull, thorax, abdomen and large superficial joints such as the knee joints.

Para. 3. That in all amputations where flaps are fashioned these must consist of skin and subcutaneous tissue only, that the muscular tissue be cut guillotine fashion at the point of section of the bone and that the flaps be left unsutured or turned back for the first 36 to 48 hours, etc.

Flaps must not be sutured at the time of the original operation.

Para. 7. In injuries of the limb there are always those who strive for excision and primary suture. Primary suture should be forbidden in battle casualties. It is a frequent cause of bad results, necessitating in some cases amputation.

There is always another day in which either to act or to regret. A secondary suture can later be performed. Don't practise primary suture except in the areas indicated above.

Para. 10. These precautionary notes were drafted because it was learned that some medical officers were contemplating primary suture of G.S.W. of the extremities.

With regard to the methods I have just discussed, another surgeon writes:

From what we have seen from the Libyan campaign and now from Syria, it seems that the "closed treatment" of wounds is well established. From a hospital point of view it has many advantages in that by reducing the number of dressings and skilled nursing attention necessary, it enables them to keep the female personnel further back and to allow those who are forward more time to look after sick cases. Also post-operative supervision is less arduous and rounds can be done much quicker, allowing the surgeon more time for other jobs. Another important advantage they have found here is the diminution of the risk of "hospital infection" of wounds. When one thinks of the increased virulence of hospital organisms due to frequent "passage" *plus* the difficult and sometimes primitive asepsis and antisepsis associated with the conditions, and that dressings are often done by orderlies who on account of their limited training and education have little knowledge of bacteria and no "aseptive sense", the closed method with the exposure of the wound once every two or three weeks for a change of plaster, usually in some sort of theatre, has considerable advantages. The additional advantages of transport, etc., have been well demonstrated in the various campaigns, especially now in getting cases back from Tobruk.

I have quoted this letter *in extenso* as it raises important points for consideration and brings up the question of "hospital infection" on which there has been considerable investigation and discussion by many leading authorities, especially in an article in the *British Medical Journal*, December 21 and 28, 1940, by several collaborators, and in a discussion at the Royal Society of Medicine reported in their *Proceedings* of December, 1940.

The main measures advocated to reduce hospital infection, apart from the control of flies and other flying or crawling pests, are as follows:

1. The minimizing of air dust by the application of spindle oil to the floors, damp-dusting, and the institution of a quiet period in the ward sixty minutes before dressing wounds.
2. The general use of large impervious masks during dressing.
3. The use of wrapped single dressings sterilized in loose bags.
4. The dressing of wounds with clean dry hands, manipulations being made with sterile forceps.
5. The careful disposal of dirty dressings and plasters, preferably into antiseptic fluid or damped sheets.
6. Sterilization of instruments in boiling 2% soda.
7. Thorough cleaning of baths, large and small, with 10% to 20% lysol and detergent abrasive powder, followed by hot water rinses.
8. The insistence on appropriate precautions during all manipulations of the wound and its immediate neighbourhood, whether by surgeon, nurse, masseur, X-ray staff, plasterers, barbers *et cetera*.
9. The attempted elimination of reservoirs of potential infection in the hospital environment.
10. The appointment in each institution of a senior nurse or medical man as supervisor and tester of aseptic and antiseptic techniques and as instructor of other members of the staff.

THE USE OF SULPHONAMIDE COMPOUNDS.

The introduction of sulphonamide drugs into the local treatment of wounds has opened up an entirely new field and one which already has been

productive of most encouraging results. Most of the experimental work has been directed towards the prevention or control of infection by the organisms chiefly concerned in the production of gas gangrene.

It has been shown that the sulphonamides will give protection against *Clostridium welchii* and *Clostridium septique*, but only to a slight extent against *Clostridium œdematiens*.

Frank Hawking, of the National Institute for Medical Research, concludes that experimental results justify the local use of sulphonamides, not only as prophylactic against gas-gangrene, but against streptococci; he also points out that such treatment should be a supplement to correct surgical measures and not a substitute for them.

It should be noted that the sulphonamide compounds have no action in preventing or delaying the development of tetanus. The compound most quickly absorbed from wounds is sulphanilamide, which in twenty-four to forty-eight hours gives in wound fluids a very high but transitory concentration of some 1,500 milligrammes per 100 cubic centimetres. Sulphathiazole and sulphapyridine are absorbed very slowly over five to ten days and give in the wound fluids a very low concentration of 104 milligrammes and 42 milligrammes per hundred cubic centimetres respectively (Hawking).

Sulphanilamide to be applied to wounds is best used in the form of the powder, although tablets should be at hand for insertion into deep pockets or tracks. The powder should be used liberally, and in recent wounds after excision there is no reason why immediate closure should not be undertaken, followed by dusting of powder on the skin surface and the application of a dressing fixed by zinc oxide plaster or even plaster of Paris. The powder should be used in all cases in which primary suture has not been possible. Even after infection has become established, sulphanilamide is of value, and clinical experience rather favours its use in place of the flavine pack, as it reduces toxæmia very quickly, relieves pain and makes the patient more comfortable; also dressings are not needed so frequently.

It may be taken that sulphanilamide is absorbed from a wound and excreted by the end of the fourth day, so that oral administration of this drug may then be commenced if necessary, 0·5 gramme being given every fourth hour so as to maintain the optimum concentration in the blood of 2·0 milligrammes *per centum*.

Mitchell, Logie and Handley, in discussing casualties from the Western Desert and Libya arriving at a base hospital (*The Lancet*, June 7, 1941), state that:

> Examples of successful primary suture of wounds were rare. . . . The failures were due to incomplete or too late excision of damaged tissues, the presence of foreign bodies, tight suturing, insufficient drainage or lack of rest; the liberal use of sulphanilamide did not neutralise the neglect of these cardinal points. . . . Tight packing was encountered several times, mainly in wounds of the extremities, and usually with deplorable results. Open wounds dressed with sulphanilamide gave better results than those with antiseptics, especially when dressings could not be changed for two or three days.

Their experiences confirm the advice given already, that no departure can be made from the essential principles governing primary or delayed primary suture of wounds.

They also considered that oral administration of sulphanilamide should never be omitted, and that it should be given in the full standard dosage or not less than 1·5 grammes three times daily for six days. If serious infection supervenes, larger doses are required for the first two days.

Referring to the local application of sulphanilamide, a surgeon writes as follows:

> We were joyfully liberal with sulphanilamide powder. We kept a big jar of it in the theatre and ladled it out with a spoon. The bigger the wound, the more powder was used. The amount was considered sufficient when every corner was liberally supplied and the wound was almost full. "Vaseline" gauze on the surface and a firm bandage or plaster "completed the trick". We have seen nearly all these wounds some two weeks after treatment and are satisfied as they are now nearly all ready for skin graft. You can imagine how much sulphanilamide was used for big buttock and thigh wounds.

There has been a voluminous literature on the local use of sulphonamides in wounds, and the salient points of each article are printed in the *Bulletin of War Medicine* issued every two months (since September, 1940), and which should be available in all medical libraries for reference.

It has been shown that sulphanilamide is the most generally useful, has no inhibitory effect in healing, is non-irritating to the peritoneum, pleura or synovial membrane, is readily soluble and absorbed, so that there is a general as well as a local effect. Sulphathiazole mixed with sulphanilamide gives the best results in the control of gas-gangrene infection and appears to enhance the efficacy of gas-gangrene antitoxin.

In view of the universal agreement as to the value of the local application of sulphonamide and the actual experiences of some of our own surgeons of the Australian Imperial Force, it is to be hoped that full supplies of this compound will be made available for use with all our surgical units.

THE USE OF ANTISEPTICS.

In *The Medical Journal of Australia* of June 28, 1941, I reviewed the current opinion regarding the use of antiseptics in the treatment of wounds, as there has been a pronounced revival of this form of therapy.

It is important to bear in mind that optimum results in the use of antiseptics can be obtained only if they are used in the correct dilution at the optimum temperature, if sufficient time is given for them to act, and if their chemical reaction to organic exudates is taken into account.

Infection by *Bacillus pyocyaneus* is a common infection and it is not generally known that there is only one antiseptic that will control it—namely, a 1% solution of acetic acid—but this has no action on other organisms which may be present as part of a mixed infection. Oxidizing substances such as peroxide of hydrogen and permanganate of potash, separately or in combination, have their greatest use in wounds infected with anaerobic organisms. Iodine is of value only on the skin, as wound exudates render it inert and it is also toxic to the tissues.

Mercurial preparations other than the recently introduced "Metaphen", "Merthiolate" and phenyl mercuric nitrate, are actually dangerous, since to be effective they must be used in such concentration and quantity that grave damage to living tissues results, and it seems that even the exceptions named are of greatest use on unbroken skin.

The only coal tar derivatives that can be considered are those in which halogenation of the cresol or xylenol derivative has been effected, such as in "Dettol", "Izal" or "Cyllin", and even then they must be used in a suitable dilution (usually 5%).

The aniline dyes, although bactericidal, are toxic to the tissues to a slight extent, but are slow in action and inhibited by wound exudates.

The flavine group are outstanding for the antiseptic treatment of wounds, as they are quick in action, highly bactericidal and have no deleterious effect

on the tissues, other than perhaps the inhibition of epithelialization if their use is continued overlong. Wound exudates or blood do not retard their activity.

In summing up, one must admit that antiseptics have a definite place in the treatment of wounds, but their use requires careful consideration and intelligent application. They can never replace immediate *débridement* and excision of recent wounds, but when infection is likely or has become established, they can be of immense value if properly used.

The Skin Grafting of Wounds.

With many wounds which have had to be packed and left open, the problem of their healing in a relatively short period of time with the minimum of scarring and contracture is one which has to be dealt with frequently. Military patients, unlike civilians, must be retained in hospitals until their wounds are healed, so any measure which will reduce hospitalization means the attainment of two important military objectives: the return of the individual to his place in the fighting machine or else his clearance from the war zone as being unfit for further service. These objectives are part of the responsibilities of the medical services and must not be overlooked, tempting as it is at times to keep a useful convalescent or an interesting case.

The time which uncomplicated soft tissue wounds take to heal depends on the original loss of tissue, the bacterial content of the wound and its treatment.

As I have pointed out previously, moist dressings slow up epithelialization of wound edges, and it is important to realize that no matter what form is adopted, antiseptic treatment should be strictly limited in its duration, as it is futile to continue for weeks on end with the same solution if it has not achieved the desired result.

A regular check should be made of the bacterial flora and on their numbers in wounds which are looking clean, so that preparations can be made for skin grafting at the earliest possible moment. Hæmolytic streptococci, of all ordinary infective organisms, have the greatest inhibitory effect on the growth of new epithelium and if any are present in a wound it is waste of time to attempt skin grafting.

Coincident with the healing of the wounds is the restoration of function, and controlled exercises should be instituted as soon as possible in all cases of limb injury.

Saline baths in a slightly hypertonic solution (2%) are useful to combat infection and at the same time to allow of exercises while in the bath; in fact, many authorities prefer this form of treatment to any other, especially for burns of the hands.

It has been found that sulphanilamide powder is the best method in clearing a persistent streptococcal infection. Apply it liberally, cover with "Vaseline" gauze and apply strapping over it, leaving it untouched for four days, when the affected area may be redressed. We have found this treatment very valuable for preparing burns for skin grafting.

One of our surgeons writes as follows:

> Apart from saline baths, other steps must frequently be taken. A wound which has been covered up ever since it was treated in a forward area will respond readily to bathing in saline with perhaps the intermittent application of eusol. On the other hand, many wounds are found to be infected with hæmolytic streptococci either at the time of their occurrence or more frequently as a hospital infection during progress to their final place of treatment. These must be treated with sulphanilamide powder.

In order to obviate the hospital infection referred to, measures as already detailed are coming into general use.

Sunbaking has been found very helpful in cleaning up wounds with persistent infection or flabby granulation, but is to be used with care and as an adjuvant to other treatment. The wound is covered with a light dressing of gauze soaked in liquid paraffin during the period of exposure, which should be graduated carefully.

For twenty-four hours before the actual skin grafting saline dressings only are applied to the wound, and it is wise to examine a smear from the surface to be sure no streptococci are present.

The actual type of graft used depends to some extent on the predilection and experience of the surgeon; but the type of wound and area to be covered demand consideration.

Tulle gras is now the favourite dressing and "Vaseline" gauze is applied over this as it has been found advisable to inspect the area daily until it is seen that there is no infection developing. If there is any sign of a purulent discharge, saline solution or eusol packs may be applied over the *tulle gras*, so that the grafts are not disturbed. If any streptococci appear, it is advisable to powder regularly with sulphanilamide.

The edges of the wound require supervision and should be painted with "Metaphen", "Merthiolate" or some such potent skin disinfectant. Mercurochrome has been advised, but this substance, if used, gives a false sense of security since it is relatively inert in a neutral or alkaline medium such as is found in discharges from wounds.

If granulations are at all excessive they are best kept flat by firm elastic pressure, such as that obtained with sponge rubber and "Elastoplast". This is to be applied in such a manner that any movement of the part will not result in a see-saw movement of the dressing on the wound, as this will disturb the graft. After four or five days the grafted area may be treated as any ordinary healing wound.

It is the practice of some surgeons to wipe away any excessive granulations with a gauze swab, but such a procedure is to be condemned as granulation tissue is the best barrier we have to the spread of infection into the deeper tissues, and if it is disturbed, any organisms present will take on a renewed activity and seriously jeopardize the chances of survival of a skin graft.

THE TREATMENT OF BURNS.

In civil practice burns are not of very frequent occurrence, so that their immediate treatment is confined to very few practitioners; but in modern warfare they are relatively common, either alone or complicating other injuries, and all medical officers must be *au fait* with modern methods of treatment.

Resuscitation methods for the treatment of shock are necessary in many cases and transfusions of dried plasma achieve brilliant results.

The usual practice has been to apply tannic acid in freshly made solution or in jelly, but it is a relatively slow method of obtaining a satisfactory tan covering. The desideratum is a dressing which is antiseptic, anodyne and which checks undue serous exudate. In most cases a general anæsthetic is necessary so that the surfaces can be cleaned efficiently before the coagulant dressing is applied. When it can be used, an intravenously administered anæsthetic is preferable to inhalation anæsthetics as the face is usually involved.

When tannic acid is to be used, the burned areas after cleansing should be painted with a 10% solution of silver nitrate before the aqueous 5% tannic acid solution is applied. This forms a crust which moulds itself to the contours of the body and does not interfere unduly with joint movements.

Most satisfactory results have been obtained by the use of "triple-dye", which consists of an aqueous solution of 1% brilliant green, 1% methyl violet and 0·1% acriflavine. It can be applied very readily on swabs, keeps indefinitely and forms a very satisfactory coagulum. It is quick in action and a good anodyne. It is important to disinfect the region surrounding the area of coagulum, otherwise infection is apt to get under the edges of the crust.

There has been some criticism of the treatment of burns of the face and hands with coagulant substances, and in their place I can recommend the daily application of a flavine emulsion or oil which allows of free movement of the parts, keeps the areas clean and promotes rapid healing.

Splinting of limbs is essential in many cases, not only for comfort, but for the prevention of contracture. As soon as the coagulum comes away, any granulating areas are treated along the lines already indicated and skin grafting is performed as early as is practicable. Sulphanilamide therapy, both local and general, is proving of inestimable value.

Conclusion.

In conclusion, I would say that although observation and experience of the treatment of war wounds is the best way of learning correct technique, there is no excuse for our medical officers if they do not know the fundamental principles of such treatment, which can be modified according to local conditions and the means of treatment available. In any event, "safety first" should be the guiding factor in the treatment of war wounds.

TREATMENT OF HEAD WOUNDS AT A FORWARD OPERATING CENTRE.[1]

By T. H. Ackland,
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The cases to be discussed in this article are cases of compound fractures of the skull, either with or without penetration of the dura. In some instances the shell fragment or bullet has left the skull through an exit wound, while in others it has still been present. All the wounds are serious, and when the dura has been penetrated, a mortality of at least 50% appears to be unavoidable.

The consideration of concussion, cerebral irritation and fractured base of the skull will be omitted, since the treatment and prognosis of these conditions in war surgery present no problems other than those encountered in civil life.

From the line to this operation centre there is in most cases a delay of not more than six hours. Thus only the minimum first-aid treatment in forward posts has been carried out, and most of these patients come to us after having had only the application of a field or shell dressing. All treatment, whether first-aid or operative, has for its main object the prevention or limitation of infection. The establishment of infection in head wounds, by reason of its disastrous results, is by no means comparable to a similar condition in a limb. At a forward operating centre it is impossible, or certainly inadvisable, to attempt excision of a wound of the brain. Consequently, when a delay of twelve hours or more is unavoidable before operation, more first-aid treatment is required than for ordinary wounds. The wound should be gently opened up and a gauze pack, soaked in acriflavine, placed in it. While this is held in place, the hair for several inches around should be clipped and then shaved. It will probably be impossible to remove all hair from the wound's edge, and this may be left for removal immediately prior to operation. The shaved skin is then painted with iodine. The gauze is removed, and sulphanilamide powder is sprinkled freely into the wound. Another acriflavine pack is now placed in the wound and held in position by a pad and triangular bandage, or preferably by a few anchoring sutures passed through the skin edges.

Arrival at the Operating Centre.

There are three possible ways in which operation may benefit these patients. Firstly, the chances of serious meningeal or brain infection can be minimized by excision of the scalp wound and by removal of blood clot, pulped brain, loose bone fragments and possibly an accessible foreign body. Secondly, and more rarely, the control of hæmorrhage from meningeal or brain vessels or a sinus may be a life-saving step. Unfortunately the vascular lesion so frequently responsible for death is a number of microscopic brain stem hæmorrhages. Thirdly, pressure from depressed bone can be removed.

A small wound in the scalp is often associated with severe brain or skull damage. Thus the first duty at the operating centre is to confirm the fact that the case presents something more than a simple scalp wound. When this is not obvious a finger covered with a sterile glove must be introduced

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to determine whether a compound fracture is present, and so whether a pre-operative X-ray examination is required. Even a fissure fracture can usually be detected in this way. The use of a probe is an inferior and unreliable method.

RESUSCITATION.

We have found that in most head injuries calling for operation little or no resuscitation is required. However, this fact must be correlated with the small delay time between the infliction of the wounds and the arrival of the patients at this hospital. Shock is certainly a minor consideration, and usually hæmorrhage has been slight or moderate. Occasionally there has been sufficient blood loss to demand a transfusion.

The most common finding is a patient lightly or deeply unconscious, with a strong pulse and in good general condition. Clinical signs of rising intracranial pressure are rarely seen.

Occasionally the patient is conscious, and in these cases, even when bone and brain damage is extensive, the chance of recovery is undoubtedly greatest.

When the patient is admitted deeply comatose, with a poor or slow strong pulse and altered respirations, the prognosis may be considered hopeless. Few of this group can be sufficiently improved by resuscitation measures to become suitable for operation.

PREPARATION.

Morphine, a quarter of a grain, meets the premedication requirements of the average case, but if restlessness is pronounced, scopolamine, one one-hundred-and-fiftieth of a grain, should also be given. Sometimes the depth of unconsciousness is such that neither premedication nor anæsthetic is required. However, increasing experience would seem to indicate that such patients have so slight a chance of recovery that in busy periods it is unjustifiable to spend on them time which would not be wasted on others. The final local preparation of the wound is carried out in the theatre. Thus when patients have received the thorough first-aid treatment which has been described, they may be brought to the theatre at once. Otherwise, as is our custom here, such preparation should be completed in an annexe or in the admission ward. Wide and thorough shaving of hair is of great importance. The actual wound edges are shaved on the operating table, with the wound pack still held in position. Finally, the skin of the scalp is prepared in the usual way with petrol, spirit and iodine. It is not generally recognized that small amounts of blood will inactivate iodine by its precipitation as iodo-albuminate. Acriflavine remains as the antiseptic which is the least harmful and the most powerful in the presence of blood. We have found that a tin hat often forms an excellent headrest. After the head has been satisfactorily fixed on this, or between sandbags, sufficient small areas are infiltrated with 2% "Novocain" solution to enable skin towels to be sutured in position. Attention must be paid to raising the lower towel sufficiently on some support to allow the entry of fresh air beneath it.

THE OPERATION.

Local anæsthesia is employed, a ring of 2% "Novocain" solution being placed at a distance of two or three inches from the wound. More anæsthetic is required for the supraorbital and deep temporal regions than for other parts, but not more than three ounces of a 2% solution may be used with safety.

The gauze pack may now be removed and the skin edges carefully and narrowly excised. The wound must now be enlarged sufficiently to allow of adequate exposure of bone. This may be done in a variety of ways. Simple prolongation of the wound's extremities with wide lateral retraction is often sufficient. We have frequently employed a curved plastic incision, or at times Cushing's tripod method. Whichever is used, the important requirement other than exposure is suture of the scalp with the least possible tension over the bony defect.

The alternative method of cutting a horseshoe flap after excision and suture of the entry wound appears to be quite unnecessary.

Hæmorrhage from the cut scalp edges is controlled by tension from everted forceps placed on the *galea aponeurotica* at intervals of about half an inch. This is quicker and more reliable than attempting to secure the bleeding points themselves.

Three groups of cases require different treatment:

1. *Fissure Fracture of the Skull.*—The skull is not opened. The scalp wound, excised but not enlarged, is sutured with a single layer of interrupted silkworm gut or silk sutures. Drainage is unnecessary, for the scalp has a considerable resistance to infection, is richly supplied with blood, and heals well.

2. *Depressed Fracture of the Skull.*—This is not infrequently the result of a shell or bomb fragment having first penetrated a tin hat either completely or partially. All loose and depressed fragments are removed. It may be possible to achieve this by use of nibbling forceps alone, but when all the fragments are tightly wedged together, a drill hole must be made at the edge of the depressed area to allow the introduction of the instrument. Only very rarely should an intact dura be opened. This step is called for on the rare occasion on which clinical signs of compression accompany a tense, blue, pulseless membrane. We have so far encountered only one such case in war surgery. With regard to the suture of the scalp, primary union over the area of bone removal must be the first aim.

3. *The Dura is Torn.*—Sufficient bone is removed to expose intact dura at all points. This facilitates the adherence of the dura to underlying brain and so minimizes the risk of a spreading infection. The tear in the dura is never enlarged. Superficially situated bone splinters are picked out, but deeply embedded fragments and metallic bodies which are not readily accessible, are left. The next step is gentle irrigation of the brain wound with warm sterile saline solution coming at low pressure from a soft rubber catheter. Blood clot and pulped brain may thus be washed out. The wiping away of debris with gauze and the use of a sucker are harmful methods and should be avoided. No attempt is made to suture the dura.

It has not been our practice to apply sulphanilamide powder locally in these cases.

Bleeding from a sinus penetration demands all possible speed in bone removal to expose it fully. If it is considered that complete exposure of the rent in the sinus cannot be quickly obtained by the nibbling away of bone, the technique of "trephining *en bloc*" must be adopted. Here the fractured bone area is cut away in one piece, four trephine holes being made with brace and burrs and united with a Gigli saw or de Vilbiss *rongeur*. In the opinion of the writer, de Vilbiss forceps of a strong pattern, and with a deep jaw, are invaluable. They are effective and sure in those instances in which a very tense dura, together with thick bone, makes use of the Gigli saw impossible.

If the sinus hole is small, the bleeding may easily be controlled by Cushing's clips, or by undisturbed pressure for several minutes over a plug

of hammered muscle. An alternative method is the use of a "postage stamp" fascial graft taken from the thigh.

If these methods are unsuccessful, the sinus must be grasped by two artery forceps, deliberately and completely divided, and ligated.

In one case great difficulty was experienced in the control of hæmorrhage from an almost completely divided superior longitudinal sinus. When it was decided to ligate the sinus completely, bleeding was found to be occurring from a torn cerebral vein which entered the sinus at this point. No Cushing's clips were available, and it was necessary to send the patient to the ward with an artery forceps holding the vein against the sinus. This was removed without trouble on the following day.

Even more important here than when the dura is intact is the securing of primary union over the defect in the skull. The separate closure of the galea by buried interrupted sutures of fine silk has been extensively practised. The writer can see no advantage in this method, except possibly in the forehead region, where its application produces a somewhat neater scar.

Drainage at one corner of the wound is a wise step, but is necessary for no longer than twenty-four hours. There is no more object in this than to prevent blood accumulating beneath the flaps, and if this is done, better healing results. To avoid leakage of cerebro-spinal fluid a suture is placed through the scalp edges at the point of drainage and left untied until the drain is removed.

POST-OPERATIVE TREATMENT.

Occasionally a collection of cerebro-spinal fluid occurs under the scalp. This is never treated by the insertion of a direct drain. It is either ignored and allowed to absorb or it may be removed by aspiration. We have not performed lumbar puncture as a routine measure on the day after operation. This appears to be unnecessary unless a clinical picture of cerebral irritation or severe headache is indicative of traumatic œdema. Later, however, it may be necessary to determine the presence of meningitis.

Two cases of *hernia cerebri* have occurred amongst our patients. One was not associated with an abscess or a retained foreign body, and although the hernia was of enormous size it responded to adoption of the sitting posture, concentrated magnesium sulphate applications and repeated lumbar puncture. The other hernia had a large abscess beneath it, and death followed.

Sulphanilamide is given orally whenever possible. A preparation suitable for intramuscular injection is substituted for unconscious patients.

STATISTICS.

Penetration of the Dura.

In the accompanying table are recorded the results of treatment in penetration of the dura. The figures for the various months have been given separately because recently fewer attempts to remove foreign bodies have been made. A relationship may exist between this fact and the greater proportion of recoveries in July and August.

Month.	Recoveries.	Deaths.
March and April	5	0
May	4	4
June	3	3
July	4	2
August	3	1
Total	19	19

Of 19 deaths two only were due to meningitis.

During the same period from March to August there were eight cases of fracture of the skull in which the dura was not penetrated. All of the patients recovered.

A striking fact is the small total number of these head operations when it is considered that 2,767 battle casualties were admitted to the hospital during these months.

Results and Causes of Death.

It would not be expected that cases in which the dura was intact should occasion anxiety.

When the dura is penetrated a high mortality—in the region of 50%—appears to be inevitable, although the small number of deaths which we have seen to result from meningitis, is surprising. This figure rises to the neighbourhood of 90% when a ventricle is involved. In our work at this centre we have had no recoveries in such cases.

In many instances in which there has been dural penetration, but only superficial brain injury, post-mortem examination has failed to disclose an obvious cause of death. One had expected that deep destruction and hæmorrhage would be found. In these cases the patients have always been comatose on admission, and have remained so until their death a day or two later.

Recent work by Rand and de Courville has shown the importance of unconsciousness as a guide in prognosis. Our experience has confirmed this. In a study of fatal cases of head injury showing no significant damage to the naked eye, they found that unconsciousness and a fatal outcome were to be correlated with microscopic hæmorrhages in the walls of the third and fourth ventricles and hypothalamus. These cause œdema around the nuclei in these regions and death. A comparison seems to exist between unconsciousness in these patients and the pathological sleep states seen in cases of hypothalamic gliomata.

Whether this explanation is the true one or not, we have often noted the more favourable prognosis in those cases in which some degree of consciousness is present. The size and even the situation of the cortical wound have not appeared to determine death or recovery.

COMPOUND FRACTURE OF THE FEMUR DUE TO GUNSHOT WOUNDS.[1]

By LEONARD LINDON,
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DURING the period January 7 to August 25, 1941, twenty-one soldiers suffering from compound fracture of the shaft of the femur have passed through an Australian general hospital. This number does not include ten cases of fracture of the lower end of the femur, with gross involvement and penetration of the knee joint. In these latter cases the problem was mainly one of the management and fate of suppurative arthritis of the knee, with infection by a hæmolytic streptococcus (which will form the subject of a separate report), while the problem of the fractured femur became of secondary importance.

The twenty-one cases which form the subject of this report were personally observed by me, and the majority were under my direct care. Although there may be nothing original in the conclusions drawn and opinions expressed, they are at least based upon personal experience, problems and failures. And they may be of assistance to those military surgeons making acquaintance for the first time with this type of fracture, either in the advanced surgical team or in the general hospital. Those who have already dealt with such cases in the forward area, who know only too well the difficulties encountered there, may not agree with some of the opinions expressed. I would ask them to remember that they are opinions only; but, being the offspring of an attempt to mate fundamental surgical principles with experience of the management of the later stages, they should at least provide food for thought and criticism.

Apart from Table I, no detailed analysis of the cases will be given, but attention will be focused upon the problems which arose during the course of management. And it is proposed to discuss them under the following headings: (i) factors influencing infection, (ii) transportation, (iii) complications noted and comments thereon, (iv) analysis of deaths and comments.

FACTORS INFLUENCING INFECTION.

Influence of the Missile.

I do not think that any useful purpose is served by an attempt to analyse the influence of the missile itself. As far as these cases are concerned (and the fractures of other bones bear this out) wounds of the utmost severity, comminution and destruction can be caused with equal frequency by rifle or machine-gun bullet, fragments of shell or mortar bomb. The destructive effect seems to depend mostly on the velocity of the missile and the power of the explosive behind it.

The Type of Wound.

Of far more importance is the type of wound produced. It is well known that a bullet wound in soft tissues often produces a minimum of trauma, followed by rapid healing, with little evidence of infection. This knowledge becomes dangerous, as it may produce a false sense of security in the early treatment. Even if there is no bony lesion, it is the exception rather than the rule to find clean perforating bullet wounds in regions as muscular as the thigh. Where there are strong muscles, there are strong fasciæ. The

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TABLE I.

Case Number.	Site of Fracture.	Retained Foreign Body.	Gross Infection of Soft Tissues.	Gross Osteomyelitis.	Residual Abscess.	Secondary Haemorrhage.	Nerve Lesion.	Inadequate Incision.	Secondary Joint Involvement.	Definite Evidence of Union. (Weeks.)	Transfers to Hospital Ship. Week from Wound.	Date of Wound.	Lung Abscess.	Amputation.	Death.
I	Middle third.	–	+	+	+	–	+	+	–	12	20	3.1.41	–	–	–
II	Upper third.	–	–	–	–	–	–	–	–	8	20	3.1.41	–	–	–
III	Trochanter.	–	+	+	–	–	–	–	–	9	20	3.1.41	–	–	–
IV	Neck.	–	–	–	–	–	–	–	–	?	20	3.1.41	–	–	–
V	Middle third.		Died on admission.									16.5.41	–	–	8.6.41
VI	Middle third.	–	+	+	+	+	+	–	–	–	–	17.5.41	+	+	24.7.41
VII	Trochanter.	+	+	+	+	–	+	+	–	10	–	4.5.41	+	–	7.8.41
VIII	Upper third.	–	–	–	–	–	–	–	–	8	12	16.5.41	–	–	–
IX	Lower third.	+	–	–	–	–	–	+	–	9	14	17.5.41	–	–	–
X	Upper third.	–	–	+	–	+	–	–	–	–	12	16.5.41	–	–	–
XI	Lower third.	–	–	–	–	–	–	–	–	9	14	16.5.41	–	–	–
XII[1]	Lower third.	–	+	+	–	–	–	–	+	?	–	21.1.41	–	–	–
XIII	Trochanter.	+	+	+	+	–	+	+	–	12	–	4.5.41	–	–	–
XIV	Middle third.	+	+	+	+	+	+	+	–	–	?	16.5.41	+	+	–
XV	Trochanter.	+	+	+	+	–	+	+	+	10	?	16.5.41	–	–	–
XVI	Upper third.	–	+	+	–	–	–	–	–	11	12	17.5.41	–	–	–
XVII	Upper third.	–	+	+	–	–	–	–	–	–	12	16.5.41	–	–	–
XVIII	Middle third.	–	+	+	+	–	+	+	–	–	–	30.7.41	–	–	18.8.41
XIX	Middle third.	–	+	+	+	–	+	+	–	?	?	10.7.41	–	–	–
XX[2]	Middle third.	–	+	+	+	–	+	+	–	?	?	3.1.41	–	–	–
XXI	Middle third.	+	+	+	+	–	+	+	–	8	?	19.7.41	–	–	–

[1] Admitted 30.7.41.

[2] Admitted 14.7.41.

bullet may continue on its way without beginning to "wobble" or spin irregularly, and will leave a small wound of exit. But even so, the effect of the impact and compression on the tough fascial septa and the elastic muscle bellies most commonly results in a destruction or devitalization of subfascial tissue out of all proportion to the size of the skin wounds. This effect is enormously increased if the bullet begins to "wobble" or deviate as the result of impact with (*a*) fasciæ or (*b*) bony structures. The wound of exit may still be small, or comparatively small; but the destruction of muscle will be most extensive, producing a subfascial cavity filled with blood clot and damaged muscle, the ideal conditions for the growth of streptococci and the establishment of an acute spreading infection of the planes of the limb. And if, in the centre of such a cavity, there lie the ends of a fractured long bone, conditions could not be more favourable for the development of osteomyelitis.

This point has been emphasized by many surgeons in Spain and in France (1940). Within a few hours such a limb becomes tense and distended by the reactionary swelling of the damaged soft tissue. Unless that tension can be relieved, the circulation within the muscle bellies is still further jeopardized and the necrotic process extends. Experience led these surgeons to practise adequate incision of such wounds. It is not enough to excise the skin margins and the ragged fascia and to clean out the accessible clot and muscle débris. Free incisions should be made longitudinally in skin and deep fascia, and then followed by transverse incision of fascia. If this is done, it is then possible for the surgeon (*a*) to empty out clot and devitalized tissue; (*b*) to ensure hæmostasis; (*c*) to remove the foreign body, if retained; (*d*) to avoid the production of serious post-traumatic tension within the limb.

By no other means can one claim to have established free drainage of a contaminated wound. And yet such free drainage is an absolutely essential first step in the treatment of wounds by plaster immobilization.

This may seem to be too radical and too time-consuming a procedure in what appears to be a compound fracture with small wounds of entry and exit. But in eight of this small series of cases it was impossible to avoid the conclusion that inadequate incision had contributed very materially to the advanced degree of bone and soft tissue infection which was present at the time of the patient's admission to hospital some twelve to twenty days after the wounds had been sustained. And in some of these cases a large foreign body was retained between the fragments of the femur. I believe that the views of Joly ("Field Surgery in Total War", 1940, pages 69 to 71) are correct, and should be read by any surgeon faced with the advanced treatment of such wounds.

When the missile has blown out a large wound of exit, the same principles of treatment should apply. But the very size of the wound renders it more likely that adequate drainage will be achieved. It cannot be too strongly emphasized that the course of the disease in battle casualties—for disease it is, sooner or later—is influenced to a greater degree by the adequacy of the initial surgical treatment and drainage than by any other factor in treatment. Because, quite obviously, it is a prophylactic measure.

Certain of these patients arrived at the base with quite large wounds, produced by missile or surgeon, and still it was necessary to enlarge them freely, as the initial fascial incision had not been large enough and the reactionary swelling of muscle bellies had filled the wounds and effectively prevented adequate drainage of the depths of the wound.

One is therefore led to summarize the essential points in the initial treatment of wounds in general and compound fractures in particular: (i) free incision and drainage, of which enough has been said; (ii) removal of foreign bodies; (iii) chemotherapy, oral and local; (iv) immobilization.

Foreign Bodies.

In regard to the removal of foreign bodies, in the presence of gross comminution of the femur it may be difficult to find the metallic foreign body, and the condition of the patient may be such that the surgeon feels constrained to immobilize the fracture with the least possible delay. But here again it must be emphasized that free incision of the wound, after localization by screening or by skiagram with a portable X-ray machine, will greatly facilitate the finding and removal of the foreign body. And it must be accepted that every effort within reason and the surgeon's judgement must be made to remove large foreign bodies which are in contact with the femoral fragments or lying in the area of pulped muscle. In this series six patients were admitted to hospital in whom large foreign bodies had been retained in these positions for at least twelve days. One patient (R.) made an uncomplicated recovery, with evidence of union present within nine weeks, and was transferred to hospital ship in fourteen weeks. But the remaining five had suffered from the most intense infection of bone and intermuscular planes. One case ended fatally, in one amputation became necessary to save life, and in the three remaining cases the patients are still developing intermuscular abscesses of thigh and buttock, after seventeen weeks of treatment.

Chemotherapy.

In my opinion every patient suffering from a deep wound with muscle trauma, with or without bone injury, should be given a prophylactic course of the sulphonamide drugs by mouth at the earliest moment, and sulphonamide powder should be introduced into the depths of the wound at the time of the first wound toilet. We have been able, over a period of nine months, to compare the condition of wounds and patients who have, or have not, been

given immediate chemotherapy in adequate dosage. And as far as our experience goes, there can be no doubt of the benefit conferred by the prophylactic use of these drugs. We prefer to follow the advice of Major E. V. Keogh as to dosage and method of administration. He has shown that a dose of 6·0 grammes, given at twelve-hourly intervals, will achieve a blood concentration of more than six milligrammes *per centum* within twenty-four hours with less distaste and nausea than will the more frequently repeated small doses; subsequent daily doses of 6·0 grammes will maintain the concentration at that level. If we expect the sulphonamides to confer a measure of protection against infection by hæmolytic streptococci, two essentials must be observed, namely: (*a*) early concentration in the blood and the wound, and (*b*) adequate drainage. Once a frank osteomyelitis and soft tissue infection by these streptococci have been established, the response to the late use of the drugs is very unsatisfactory in some of these cases. And too much effect should not be expected in cases of osteomyelitis and abscess formation due to mixed infection. Therefore, if these drugs are available, use them early.

TRANSPORTATION.

In the earlier stages of the Libyan campaign five patients were sent down in Thomas splints on a long, tedious and very rough route of evacuation. They suffered greatly, and on arrival at an Australian general hospital four days after the infliction of their wounds, they were in very poor condition, simply as the result of the difficulties of immobilizing a fractured femur for four days on a Thomas splint with fixed extension. But during the siege of Tobruk, the patients with fractured femur were transported in well-fitting plaster spicas, applied at an Australian general hospital. And although they were frequently already the subjects of acute infection, the general condition of these men on arrival at an Australian general hospital was remarkable. They had been evacuated by destroyer and train, and had often been three days on the way. Their temperatures may have been elevated, but they felt comfortable, had been able to rest and looked well. The plaster spica seems to be the ideal method of fixation for transport.

They were allowed to rest and settle down for thirty-six to forty-eight hours, during which time X-ray examination of the fracture was made by portable unit. This "breathing space" was important; they got sleep, food and rest, and in many cases the pyrexia diminished. In the majority of cases it became necessary then to remove the plaster spica for the purpose of correcting malposition, drainage of wounds or removal of foreign bodies. Treatment was then carried out by skeletal traction with Kirschner wire on a Thomas splint. The men themselves were glad to come out of plaster, for obvious reasons of nursing and skin cleansing, and enjoyed the greater freedom of movement. But they all realized how much the spica had contributed to their well-being during transportation.

The comparatively smooth and comfortable transportation of these patients in plaster spica is a strong point in favour of the view that all units acting as advanced surgical centres should be equipped with apparatus suitable for the application of a well-fitting plaster hip spica.

Comment.

There are certain definite drawbacks to the prolonged use of plaster in these cases of gross osteomyelitis.

1. These patients rapidly lose their subcutaneous fat, and their skin becomes susceptible to a degree of pressure which, in the non-toxic patient, would lead to no skin complication; the plaster becomes loose and ill-fitting,

often in four or five days; this of course means that control of the fragments and limb is lost, and the movement within the plaster increases the tendency to the formation of pressure sores. Immobilization is lost and malposition can occur.

One has to choose between frequent changes of a plaster spica, distressing to the patient, or treatment by extension on a Thomas splint.

2. These patients are all febrile and have a raised pulse rate. While they are in plaster, therefore, it may be extremely difficult to determine whether an intermuscular abscess is developing. And while it is the opinion of some surgeons that these abscesses will resolve when immobilized in plaster, it has not been our experience, and one feels happier to be able to observe the course of such a complication and to institute drainage at the appropriate time. One of the deaths in this group is a striking example of the difficulty of knowing what is going on within a plaster spica (Case XVIII).

Prior to embarkation a spica was again applied, but again essentially as a means of transportation. Non-union was not considered as a contra-indication to transference to a hospital ship. Regardless of the degree of union, these patients were transferred to a hospital ship as soon as it became reasonably certain that the infection had subsided to such an extent as to be unlikely to cause further complications.

COMPLICATIONS.

Osteomyelitis.

Gross osteomyelitis occurred in 14 cases out of 21. And when it did occur, it initiated a series of changes which fortunately are seldom seen in cases of compound fracture of the femur in civilian practice.

A temperature (swinging to 103° F. or more) and a pulse rate of 130 to 140 per minute may persist for weeks, even when the wound and bone appear to be draining freely. Absorption from the infected medullary canal of the femur must be the cause of the prolonged systemic changes, which are so severe.

Loss of appetite and lack of restful sleep contribute to one of the worst features mentioned above, the very rapid loss of fat and muscle wasting, with atrophic shiny skin and marked tendency to the development of pressure sores, which, once begun, spread relentlessly in area and depth.

To this is added the rapid development of secondary anæmia of severe degree. We have endeavoured, by the frequently repeated use of fresh blood, to keep the hæmoglobin content above 60%. Fresh blood appears to have been of more value than stored blood. Up to a point, the hæmoglobin percentage is a useful index of the prognosis of the case. A steady or rising content, after some weeks, indicates that the patient will probably save his leg. A content which falls regularly and rapidly after each transfusion generally indicates that the time has come when the leg must be lost in order to save life.

Three patients have developed multiple pulmonary abscesses; in two of these cases the condition was part of a terminal septicæmia. The third patient is still alive, five weeks after the first evidence of a pulmonary lesion; but the development of a pyopneumothorax during the last week renders his prognosis very grave. His leg was not amputated until it was realized that he had a pyæmic infarct of the lung; it is easy to look back and see that amputation was deferred too long. This will be referred to later.[1]

[1] October 10, 1941: This patient's condition is very considerably improved and his chest is draining considerable quantities of thin fluid; the fistula appears to be closing; the drainage apparatus will maintain a small degree of negative pressure. His weight is increasing and his colour is improving. He is eating well.

Residual Abscess.

The most troublesome abscesses have been those which have arisen in association with wounds in or near the buttock and a high fracture. Dependent drainage is difficult to maintain owing to the fact that the wound or drainage incision is occluded by the pressure of the patient's weight on the buttock. An abscess deep to the *gluteus maximus* and *fascia lata* may pocket again and again, frequently requiring fresh incisions for drainage. And such abscesses continue to give trouble long after union has occurred. In two of our cases the infection has finally spread to the hip joint.

Rate of Union.

It has been very striking to note that in ten cases clinical and radiological evidence of union was present within twelve weeks, and the shortest period was eight weeks from the infliction of the wound. And most of these patients were the subjects of gross infection. Unless massive death of bone has occurred, the reaction to infection appears to be a definite stimulus to callus formation. Within limits, the comminution invariably present also favoured early callus formation.

Secondary hæmorrhage occurred in only two cases, and in one of them it was of no gravity. The second case will be discussed more fully in the analysis of deaths.

Nerve Lesions.

Nine patients suffered from varying degree of involvement of the sciatic nerve or its main branches. In four of the nine cases the lesion was noted at the first examination in the forward area. In the remaining five cases nerve involvement has developed subsequent to the infliction of the wound. This observation has frequently been made in cases of grossly infected wounds in other regions, and has been seen in wounds of soft tissue only. The loss of function is frequently associated with considerable pain, and is probably due to an infective perineuritis, consequent upon the spread of suppuration in the vicinity of nerve trunks. And recovery does not commence until the reaction in the wound has become quiescent.

A genuine causalgia occurred in one case only.

ANALYSIS OF DEATHS.

CASE V.—The patient was admitted to hospital on June 8, 1941, during my absence. He was suffering from gross infection and severe toxæmia. He died within an hour of admission. No autopsy was performed.

CASE VI.—The patient was wounded on May 17, 1941, and was admitted to hospital on June 4, 1941, suffering from a compound comminuted fracture of the mid-shaft of the left femur and a wound of the calf, with the foreign body retained. Gross infection of both wounds was present; the patient was very "toxic" and sick; he was very emaciated. There was a large and dirty four-inch wound over Hunter's canal, which had been tightly plugged; on removal of the plug the day after the patient's admission, much pus escaped and was followed almost immediately by a profuse secondary hæmorrhage. A tourniquet was applied; the patient was taken to the operating theatre and given a blood transfusion. Major Ross, in charge of the patient, urged amputation. I advised conservative and expectant treatment, after ligation of both ends of the artery in Hunter's canal. This was done, and for two weeks it appeared that the leg would be saved. The patient then became rapidly worse, and developed some gangrene of the toes, and on June 22, 1941, a rapid amputation was performed. By this time the patient was extremely emaciated, and in spite of repeated transfusions he went steadily down hill, and died on July 24, 1941. Post-mortem examination revealed evidence of general septicæmia, with multiple tiny abscesses in the lungs.

It is probable that, if Major Ross's advice had been taken, this man's life would have been saved at the expense of his leg. As events proved, we delayed too long before sacrificing the leg, and by then general septicæmia had

supervened. Is it fair to say that secondary hæmorrhage *plus* a grossly infected compound fracture of the femur means amputation? Personally, I think not; but in this case I believe that we lost the patient, not because we did not amputate at once, but because we delayed too long, failing to realize when the patient had reached the danger point.

CASE VII.—The patient was wounded on May 4, 1941, receiving a compound fracture of the right femur in the intertrochanteric region and wounds of the back and slight blast injury to the lungs. For a week he was treated on a Thomas splint with fixed extension because the pulmonary lesion was critical; by this time he already had commenced the development of a series of pressure sores which played a major part in the production of the terminal septicæmia. He was then transported in plaster spicas and finally reached this hospital on June 5, 1941, in a very ill-fitting spica which did little but aggravate his pressure sores. (This is not criticism of the surgeon who applied the plaster; this patient was a striking example of the difficulties and dangers of plaster technique; but one did feel that at one stage he had been left too long in one plaster). Consequently, on his admission he was in a pitiful condition. Eleven pressure sores were counted on bony prominences from the waist downwards, and he was extremely "toxic", weak and anæmic. Such was his condition that he had to have a two-pint blood transfusion before he could be taken to the theatre for removal of the plaster spica. Again, being wise after the event, I feel that his life would probably have been saved if the leg had been amputated forthwith; I should have realized that any type of skeletal traction or immobilization must also immobilize the patient, and so prevent or interfere with treatment directed to the healing of his grossly infected pressure sores (subsequently found to be due to hæmolytic streptococci, *Streptococci fæcalis* and coliform bacilli). His extreme emaciation, with atrophic skin and hectic temperature, should have made this obvious. But skeletal traction was applied by a wire through the tibial crest on a Hodgen splint, and evidence of union was actually present by the tenth week. But, none the less, he was going down hill and developed, as in the former case, multiple lung abscesses before death.

Every surgeon is loath to amputate through the thigh unless he can sees no other means of saving life. The last twenty years have shown us that the working-class man with mid-thigh amputation from the last war found little room for himself in the labour market. And one is liable to forget that our first and most important object is to save life. These two cases illustrate the fact that in watching closely the local condition, one may easily overlook the patient's general condition, which is the only reliable indication of the man's power of resistance. When faced with the necessity of deciding whether the time to sacrifice the leg has arrived, I feel that the most important considerations are (*a*) the appetite, (*b*) the pulse rate, (*c*) the rate of fall in hæmoglobin content, and (*d*) the rate of emaciation. We have erred on the side of conservatism, with regret. One must amputate before signs of septicæmia develop. Inevitably a few legs will be lost, perhaps unnecessarily; but fewer lives will be lost.

CASE IV.—The patient was wounded on July 30, 1941, suffering a grossly comminuted fracture of the middle of the right femur, with a large and severely infected wound on the posterior aspect of the thigh. He was admitted to hospital in a plaster spica on August 10, 1941, in a febrile and toxic condition. He was observed for two days, and then on August 13, 1941, the spica was removed and the wound explored. There was no external evidence of abscess formation, and the limb was reduced and again put up in a close and well-fitting spica. Two days later the patient became acutely ill. The temperature, which all along had been swinging to 102° F., rose to 105° F., with a rigor, and his condition suggested the onset of an acute septicæmia. Meanwhile the toes of the right foot had become cold and cyanosed, but not swollen, and he had no feeling in the toes. There was a positive blood culture of hæmolytic streptococci. He went down rapidly and died on August 18, 1941.

Post-mortem examination revealed no evidence of septicæmia. But an abscess had formed in relation to the end of the proximal femoral fragment, and the close-fitting spica had prevented the local swelling of the limb. Pus had therefore forced its way up the intermuscular planes in two directions, (*a*) through the obturator foramen into the pelvis, where pus was found outside the pelvic fascia, and (*b*) tracking up within the psoas fascia, and pus was found in the psoas muscle as high as its origin from the first lumbar vertebra. Death was considered to be due to overwhelming absorption under tension from these abscesses. There was no thrombus in the femoral artery,

and the occlusion of the artery was the result of the tension developed in the limb within the relentless grip of the spica.

It is obviously unwise to generalize on the findings of but one proven case. But the history of this patient, who was under the immediate care of an orthopædic surgeon in this hospital, supported my preconceived ideas concerning the drawbacks to the treatment of fractured femora in plaster spica when once a severe infection has become established in the muscle planes; in the bulky and elastic muscles of the thigh it may at the best of times be difficult to be sure of the presence of a deep-seated abscess. When the surgeon is excluded from the evidence to be gained by palpation and visual examination of the suspected thigh, the diagnosis of pus becomes mere guesswork, as this case showed. The preexisting osteitis has already produced a swinging temperature and increased pulse rate and pain. Local examination alone can indicate the need for further incision and drainage. And therefore I feel that in these obviously infected cases the patient should, apart from the demands of transportation, be treated by skeletal traction on a Thomas splint.

FRACTURES IN THE FIELD.[1]

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GENERAL CONSIDERATIONS AND WORKING CONDITIONS.

THIS article is based on experiences in the first Libyan and the Syrian campaigns, and is intended as a supplement to Lieutenant-Colonel Julian Smith's article published in the January issue of THE AUSTRALIAN AND NEW ZEALAND JOURNAL OF SURGERY. It is based on the experience gained by Lieutenant-Colonel Smith, myself and Captain Robert Officer.

Before proceeding to the discussion of wounds and fractures, I must describe briefly the conditions prevailing in Libya and in Syria.

In the first instance, it must be realized that the casualty clearing station, as a unit, was developed in France during a period of trench warfare, and that its establishment is still substantially the same as it was in 1918, though as the result of experience gained during these later campaigns, it is being modified at the time of writing.

The fact that the war in the Middle East has been entirely a war of movement, has given rise to many new difficulties because of the comparative immobility of the unit, by modern standards, in relation to the general scheme of action. For example, it has been impossible to establish the casualty clearing station as close to the front line as formerly, and as in both these campaigns our troops advanced relatively rapidly, the line of evacuation to the casualty clearing station became rapidly very much longer.

In the Libyan campaign the unit was first established in a series of basements in a large Egyptian barracks beyond Mersa Matruh (these barracks having been rapidly evacuated by the Egyptian Army on the appearance of Marshal Graziani's forces at the border). The conditions for working were not good, owing to frequent sandstorms and restricted water supply, also owing to certain deficiencies in equipment, particularly plaster of Paris, and the lack of a generator for the X-ray plant. Later on, in Syria, on the other hand, the conditions left nothing to be desired and compared favourably with those prevailing at the general hospitals.

The unit capacity of fifty beds and one hundred and fifty stretchers was frequently exceeded, and this made the task of the nurses and nursing orderlies very difficult, because reinforcements were at that time unobtainable. Admissions were at the rate of about a hundred per day, so that it was necessary to find the same number of patients daily who were fittest for evacuation. This naturally had some bearing on the methods of treatment adopted, one of the main objects being to render the casualties fit for evacuation as early as possible.

Patients arrived at the casualty clearing station by motor ambulance convoy. In Libya, the line of evacuation was long and over roads so bad that in many places three miles an hour was the highest speed obtainable, and even at that speed the jolting was very considerable. I experienced this myself by way of experiment as a "lying case" and can testify that two hours of such travelling was exhausting, even for an unwounded man.

The patients arrived on an average thirty-six hours after receiving their wounds—the earliest arrived in twenty-four hours and the latest in three days. Many of them had already received surgical treatment further forward

[1] Accepted for publication on March 4, 1942.

at the advanced surgical teams (*vide* Lieutenant-Colonel Julian Smith's report). It can be easily understood, however, that many patients arrived in an extremely shocked and exhausted condition.

Evacuation was by motor ambulance to railhead at Mersa Matruh, and thence by ambulance train, or alternatively by hospital ship to Alexandria.

In Syria the line of evacuation was very much shorter and over better roads, so that patients were received earlier. They arrived frequently within twelve hours of injury, but many wounds were very much older because the stubbornness of the French defence, the siting of their fixed machine-guns and the mountainous nature of the terrain made collection of the wounded a matter of extreme difficulty.

Evacuation was by motor ambulance to railhead at Haifa and then by ambulance train to Gaza, Rahovath and Sarafand. The nature of the terrain in both Libya and Syria was such that gas-gangrene was a rarity. The land had not been heavily cultivated, as in Flanders, and the hot dry air rapidly desiccated any excreta, so that gas infections were only a minor problem. Actually none passed through the unit in Libya and only five in Syria. In neither campaign did any gas-gangrene infection develop subsequent to arrival of the patients at the casualty clearing station.

Dehydration of patients was often a prominent feature, because of limited water rations and the length of time between their receiving the wound and being collected by the bearers.

TYPES OF FRACTURE.

Having tried to present a brief picture of working conditions in the unit, I shall now proceed to a consideration of the fractures.

About 86% of all wounds seen occurred in the limbs.

Nearly all the fractures seen were compound, and due to gunshot wounds —rifle, machine-gun, high explosive, grenade and mortar grenade wounds, besides those from aerial bombs and explosive cannon shell from aeroplanes.

A few simple fractures were seen, due to blast and other causes, but my remarks on immobilization apply equally to them, so that there is no need to consider them separately.

From the nature of the missile the wounds can be broadly classified into: (i) Through-and-through wounds, either punctured or lacerated, or with a punctured wound of entry and a lacerated wound of exit. A few self-inflicted wounds were seen, with the wound of entry lacerated and larger than the wound of exit and surrounded by powder burns. (ii) Wounds with retained metallic foreign body. These can also be divided into those that have a punctured and those that have a lacerated wound of entry.

The value of such a classification is that it gives a lead as to whether the wound is a bullet wound or due to some other type of missile. If it is a bullet wound of the through-and-through type, the probability is that no metallic foreign body remains, or if there is no wound of exit, that the bullet will be found distorted, but in one piece.

If the wound is due to other types of missile, these will frequently be found to have fragmented, so that an X-ray photograph shows the whole area of the fracture stippled with tiny metallic fragments, whose removal is quite impossible.

Except as a guide to what one may expect to find, the classification is academic, because the operative treatment (if any) remains the same.

A through-and-through punctured wound is no indication that the damage to bone and soft tissues will be any less than the damage associated with a large lacerated wound. It is well known that the course of a bullet or other

missile in the body is unpredictable, and this is particularly the case after it has impinged on bone.

By far the commonest fractures were below the knee and below the elbow. Fractures involving the bones of the hand and foot were common—in the former case sometimes due to the insatiable curiosity of the private soldier in investigating the mechanism of captured enemy grenades. These patients were admitted, often with a surprised expression, one hand blown off and their carpal bones or fragments of them distributed throughout the lower third of the forearm. Fractures of the femur and humerus were less common, and we saw still fewer fractures of the pelvis and shoulder girdle.

Besides actual battle casualties, we saw a large number of compound fractures of both bones of the leg, due to road accidents, the patients being chiefly motor cyclists. At one period thirteen despatch riders were admitted with this injury in nine days.

Many of the fractures were complicated by the involvement of joints or nerves, a few by the involvement of large vessels, and many by the presence of other wounds.

CONDITION OF THE PATIENT ON ARRIVAL.

As I have already pointed out, many of the patients were extremely exhausted, shocked, exsanguinated and dehydrated on arrival, and in all cases the first consideration was to assess the degree of shock and to institute the appropriate treatment, even before disturbing the dressings. I was very impressed with the efficacy of the simple measures which I think are rather apt to be forgotten or neglected in these days of intravenous therapy.

This treatment fell naturally under several headings.

1. *Relief of Anxiety.*—For the relief of anxiety, if for no other reason, a casualty clearing station should be sited in as safe a place as feasible—if possible, beyond the sound of gunfire—and it should at least appear to be well protected against aerial bombardment or "strafing". From this point of view we found the presence of the nurses of great assistance. The mere sight of them produced a beneficial effect on the morale of the patients.

There was, of course, a general dread of amputation, so we made a point, whenever possible, of reassuring patients that there was no question of their losing a limb.

A hot drink of tea immediately after arrival was a routine, unless specifically forbidden by the receiving medical officer, and immediately after being seen by the surgeon all patients received a hot meal, except those due for the theatre within the next three hours or so. Often this was the first meal for twelve to eighteen hours, the previous ones consisting of "bully beef" and biscuits.

All patients arrived with several days' growth of beard, and the two unit barbers began shaving them in turn, immediately on the arrival of a convoy, while nursing orderlies started washing those patients whose condition permitted it. Funnily enough, the hot meal within ten minutes of arrival and the shave were the things that made the reputation of the unit among the troops.

So much for the general treatment of all patients on arrival.

For patients with compound fractures and minor grades of shock, when there had not been excessive hæmorrhage, hot drinks, morphine, rest and warmth and a cigarette to smoke were generally sufficient to produce a marked response in an hour or so, when operative treatment could be undertaken.

In the more severe cases, in addition to these measures, blood transfusion and the intravenous administration of saline solution were used with excellent

effect. I cannot stress too much that no patient should be submitted to operation until his general condition warrants it.

2. *Treatment of the Fracture.*—All patients had, of course, received treatment at the main dressing stations—dressing of wounds, application of splints *et cetera*—and in Libya many of those more seriously injured had been dealt with surgically by the advanced surgical teams. More mention will be made of these points later.

The work of the field ambulance was excellent. They made mistakes in the early stages, as we did ourselves in the casualty clearing station.

Now the only places where adequate treatment of compound fractures in the field can be carried out are, firstly, with the advanced surgical teams (if any) and, secondly, at the casualty clearing station.

OBJECTS OF TREATMENT.

The objects of treatment are the same as in civil practice, of course; but the importance of the various objectives is different: (i) prevention of infection, (ii) adequate treatment of infection if it has already developed. (iii) reduction, (iv) immobilization. All these objectives cannot always be achieved, and frequently a compromise must be reached.

I shall now discuss the treatment under various headings.

PROPHYLACTIC TREATMENT.

We have been very fortunate in having at our disposal the drugs of the sulphanilamide group, and it is largely due to them that the results have been so very good. The routine treatment of all wounded has included the administration of sulphanilamide or sulphapyridine, whichever was available, at the regimental aid post and again at each staging post in the journey to the base. In the Libyan campaign four tablets were given at each dose, and when the ambulance journey was longer than four hours, the patients were given more tablets to take *en route*. In the Syrian campaign an initial dose of ten tablets was given at the main dressing station.

In addition to the oral administration, sulphanilamide powder (crushed tablets) was applied to the wounds, which were then dressed with "Vaseline" gauze.

The incidence of clinically infected wounds was extremely small on arrival at the casualty clearing station, though the majority were of thirty-six to forty-eight hours' duration. When clinical infection was present, it could in some cases be traced to improper treatment, such as the plugging of wounds of entry and exit. In other cases, infection occurred in patients who had suffered from considerable blood loss, and this was one class of case in which we found blood transfusion of great value.

OPERATIVE TREATMENT: DÉBRIDEMENT.

To my surprise, I found that there still exists considerable doubt as to the meaning of the term *débridement*. To some medical officers it apparently means only the excision of skin edges and superficial tissues, and this without adequate preparation of the skin.

Our practice in the casualty clearing station was as follows. With the patient under general anæsthesia, the clothing was cut away if this had not already been done. The dressings were removed and the whole limb, or as much of it as possible, was scrubbed with a nailbrush and soap and water, and then shaved. The skin was then prepared with ether soap, benzine, spirit and iodine. Sterile towels and sheets were applied as usual, except that great economy of linen, consistent with safety, had to be practised.

These steps were performed by an assistant, usually a medical officer, but sometimes by the dental officer or dental staff sergeant. This procedure may sound elementary and not worth recording, but it was surprising how often one or more of the steps had been omitted in cases further forward in Libya.

The surgeon worked in gloves and mackintosh apron. Gowns were not worn except for abdominal, brain and open chest wounds, owing partly to shortage of supplies, but chiefly because of our limited autoclave capacity and laundry facilities.

The instruments used were of the simplest and were put up in "general sets" and "special sets" wrapped in sterile towels. In addition, there was a table covered with a sterile sheet on which the remainder of the instruments were kept, already sterilized, under sterile towels. As one operation was finished, the general set of instruments used was resterilized and the other set was used for the next operation.

At operation the skin edges were excised (as little skin as possible being sacrificed) also the soiled and damaged subcutaneous tissues, and the edges of the wound in the deep fascia. Then, with a fresh knife, the deep fascia was widely opened, clot was evacuated from the depths of the wound, and all damaged muscle was excised. At this stage the shell fragment or other missile was often found and removed. In some cases, especially in the thigh, it was impossible to remove all damaged muscle, but as much was removed as possible.

If the metallic foreign body could not be found, or was fragmented into small pieces, no very extensive search was made for it, but every effort was made to ensure that no fragments of clothing or other foreign matter were left *in situ*.

The fractured bone ends were inspected, as far as possible, and wherever dirt was ingrained or adherent, this was dealt with by means of a mallet and chisel or a Volkmann's spoon. Comminution was the rule rather than the exception, and fragments of bone had to be removed from the muscles, also fragments obviously lacking any blood supply.

The wound was then thoroughly irrigated with normal saline solution. Powdered sulphanilamide was applied to the wound, either by spraying it into the wound from an ordinary atomizer or else by introducing it into the depths of the wound in a Volkmann's spoon or spreading it into all the recesses of the wound with the tip of a gloved finger.

Our practice was then to fill the wound with "Vaseline", level with the skin surface, and then to apply "Vaseline" gauze flat over the whole wound and a massive dressing over this. We avoided packing the wounds with "Vaseline" gauze because plaster splints were used in many cases and because packing is open to abuses. I have seen compound fractures of the humerus and femur put up in closed plasters, when "Vaseline" gauze had been packed into a through-and-through wound from end to end, passing even between the fractured bone ends! I may say that it is a heart-breaking job trying to disentangle gauze from jagged and spiculated bone ends in the depths of a wound. So we abandoned packing altogether and made it quite clear on the field medical card that there was no packing in the wound. We found it much easier to get the "Vaseline" to stay in the wound if sufficient liquid paraffin was added to give the mixture approximately the consistency of cold cream.

COMPLICATED FRACTURES.

Involvement of joints, especially the knee joint, was common. When the joint was widely open or the missile had passed through the joint, it was dealt with along orthodox surgical lines. Hæmarthroses from fractures of the femoral or tibial condyles, for example, were aspirated.

No attempt was made to perform deliberate nerve suture or to search for severed nerve ends, but if the ends were seen, they were approximated by one or two fine sutures. When a main vessel had to be ligated, closed plasters were not used.

Reduction of Fractures.—In the circumstances, reduction of fractures was regarded as the least important of the objectives to be attained.

In the majority of cases it was possible to obtain good reduction and to maintain the position, but if it was not possible to reduce the fracture easily, the limb was put up in the best position which could be obtained without waste of time or exhaustion of the patient, the reason being that the main problem was the safe and comfortable transport of the patient to the general hospital, and not the obtaining of perfect anatomical alignment. These remarks apply chiefly to fractures of the femur, because it was in these cases that the greatest difficulty was experienced.

X-Ray Examination.—At the outset of the Libyan campaign we were handicapped by the lack of any generator for the X-ray plant. Later Major E. R. Crisp managed to "acquire" an Italian one, which worked very well after he and his technicians had dismantled and reassembled it.

Preliminary films were taken in two planes before operation, in order to show the fracture and the position of any foreign body.

In the early stages we made use of localization of foreign bodies by means of the X-ray screen, the estimated site and depth being marked on the skin. The drawback to this method was the moving of the patient from X-ray table to operating theatre. This often caused a change of posture, which made the skin markings not only useless but actually misleading.

Films were also taken after operation, for position, and all films accompanied the patient on evacuation.

GENERAL REMARKS ON OPERATIVE TREATMENT.

When operation had been undertaken further forward, we found it of great value to have the signature of the surgeon on the field card, because it was then possible in most cases to leave the splint and dressing undisturbed unless special indications for interference existed, knowing that the wound had already been adequately treated.

One of the most difficult problems was to decide when to leave the wound alone and make no attempt at *débridement*. This problem occurred particularly in Libya, when the wound varied in duration from one to three days when first seen. The decision had to be made on the merits of each individual case, but as a broad generalization wounds of more than thirty-six hours' duration were not disturbed, except by such manipulations as were unavoidable in putting up the fracture.

Anæsthesia.—The routine anæsthetic was ether given by the open method. As time went on gas and oxygen were used less and less. No single spinal anæsthetic was given, nor was local anæsthesia used.

Amputation.—I was surprised to find how rarely it was necessary to resort to major amputations, though amputations of fingers and toes were relatively common.

Amputation of hopelessly mangled limbs had nearly always been performed further forward, at the main dressing station or by the surgical teams. These were usually of the guillotine type, and the patients arrived with the stumps in good condition. So also did the patients whose flaps had been cut and turned back, and those patients for whom it had been possible to cut long though unorthodox flaps and to approximate the ends by one or at most two sutures over a large "Vaseline" gauze pack. This procedure was in

no sense a primary closure, as the flaps were at least double the usual length, loose and floppy, and plenty of room was left for removal of the "Vaseline" gauze pack, inspection of the stump and replacement of the pack. Cases in which flaps such as these were obtainable were naturally uncommon.

No more than twenty major amputations were performed at the casualty clearing station. These were done for the following reasons: (i) gas gangrene, five cases; (ii) gangrene due to a tourniquet having been left on (in the field) for nineteen hours, one case; (iii) badly comminuted fractures with much muscle damage, which were already grossly infected; (iv) cases in which the blood supply was destroyed, or the hand or foot blown off.

In the case of the leg, we preferred disarticulation through the knee to amputation through the lower third of the thigh, because of the small amount of muscle divided in this operation and the fact that secondary amputation was facilitated. Whenever possible, flaps were cut and turned back.

Primary closure is a criminal procedure. I have seen two cases in which set amputations through the thigh with primary closure without drainage had been performed. Both these patients nearly died.

IMMOBILIZATION OF FRACTURES.

Immobilization of fractures was of prime importance, and methods had to be devised to immobilize them under conditions of transport over extremely rough roads for very long distances. On account of the long distances, methods which were satisfactory under conditions prevailing in France were found to be entirely unsuitable.

Fractures of the Upper Limb.—Fractures of the humerus presented very little difficulty. They were put up at first in the ordinary way with the arm bandaged to the side. Later, when plaster became available, it was found that the patients travelled more comfortably in the same position if a plaster slab was applied from the shoulder down the dorsal and lateral aspect of the arm and forearm and another small slab was applied along the medial aspect of the arm, from axilla to elbow, the arm then being bandaged to the side with a few turns of plaster bandage. Abduction splints were not used because they do not sufficiently immobilize the arm. Abduction plasters were used occasionally, but were avoided when possible because of difficulty in transport with the arm projecting beyond the side of the stretcher.

Fractures in the region of the elbow joint and below the elbow were put up either in closed plasters or by means of plaster slabs, and the arm was then put in a sling.

Fractures of the Lower Limb.—It was in fractures of the lower limb that the greatest difficulties were encountered. The patients were transported as far as the casualty clearing station, and the fractures were put up in Thomas splints with fixed extension applied in various ways. I shall consider these first of all.

It was often difficult or impossible to obtain a correctly fitting Thomas splint for each individual patient. In general, the rings of the splints supplied were too small and were incorrectly shaped, so that pressure tended to be taken on the perineum rather than the ischial tuberosity, with great discomfort to the patient.

The Thomas splints were attached to stretcher suspension bars, and unless great care was used in tying the splint as tightly as possible to both uprights as well as the bar itself, a lateral sway developed which was most distressing to the patient.

With regard to extension, it must be realized that a very much greater degree of extension was necessary than in the case of a patient with a similar fracture lying in a hospital bed.

The methods of applying the fixed extension were various.

1. A clove hitch was applied over the boot. While perfectly satisfactory for short periods, this method was unsuitable for conditions in Libya, where it had to be used for a much longer period. In every case there were commencing pressure sores on the dorsum of the foot and over the *tendo Achillis*. In two cases that I saw, the boot had been removed and a clove hitch applied over the sock only, and in these the pressure sores were well developed.

2. A pin passed through the boot was much more satisfactory and appears to be one of the best methods; but there is still a lot of pressure on the dorsum of the foot and upper part of the heel, which gives the patient a good deal of pain after it has been on for any length of time.

3. The same remarks apply to the third method; this is a spring clip which grips the boot just above the sole in rather the same manner as ice tongs.

4. Strapping extension is applied with spreader or Sinclair's footpiece. Some of these patients travelled comfortably, but in the majority of instances the strapping showed a decided tendency to slip, in which case the patient suffered badly.

The methods of immobilization of the lower limb employed in the casualty clearing station were two: (i) Thomas splint with skeletal traction, (ii) some form of plaster splint.

I propose to deal only with compound fractures of the femur and tibia and fibula.

COMPOUND FRACTURES OF TIBIA AND FIBULA.

The routine was to put up compound fractures of the tibia and fibula (after *débridement*) in closed plasters. We had a limited stock of "Cellona" bandages. These were ideal, because the plaster slabs could be made by an assistant, dry, and be ready for application by the surgeon as soon as the operative procedures were complete. Also the plasters could be made lighter than with the plaster bandages prepared by the orderlies.

The plasters were applied directly over the shaved skin except over the wound, where a massive dressing was first applied to soak up discharge from the wound. It was not our intention that these plasters should be left on for any length of time after the arrival of the patient at the general hospital.

The usual routine was to apply a plaster back slab, and to complete the plaster in the ordinary way by means of plaster bandages. These plasters were kept as light as possible, consistent with safety, particularly over the site of the wound, the position of which was marked on the outside of the plaster. Particular care was taken to mould the plaster closely around the knee, which was also slightly flexed, in order to prevent rotatory movements of the leg. These patients travelled perfectly comfortably, unless they had to be kept in the casualty clearing station for several days, when the plaster became loose enough to allow considerable movement. Unless contra-indications existed, they were only kept for thirty-six to forty-eight hours. I must admit that I always watched these patients with some misgiving and considerable anxiety, particularly as it was relatively common for temperatures to go to 100° F. or even more, about twelve hours after operation, and to stay up for about twenty-four hours.

When there was evidence of clinical infection, closed plasters were not used, nor in the older wounds when *débridement* was not done, unless the wound looked healthy and the temperature was below 99° F. In those cases we used the Thomas splint with skeletal traction, and a footpiece attached to the splint to keep the weight of blankets off the toes.

At first in Libya we had no Kirschner wires, and tried strapping extension, which we found extremely unsatisfactory. We therefore fell back on the use of Böhler's pins, which served their purpose perfectly well. Later we were fortunate enough to acquire a large number of stainless steel bicycle spokes which were easily converted to Kirschner wires. Still later an adequate supply of Kirschner wires became available, and from then on we used no other form of skeletal traction. In a few cases we used Kirschner wires and plaster together, when it was necessary to maintain traction while the plaster was being applied.

After the leg was put up in the Thomas splint with skeletal traction, the whole limb was bandaged around the Thomas splint from the ring of the splint down to and including the foot and footpiece. This was done to minimize rotatory movements of the limb. For the same reason, the stirrup of the Kirschner wire was tied to the side bars of the Thomas splint.

The Thomas splint was always bent slightly and great care was taken to ensure that the angle of the ring was so adjusted that the pressure was taken on the ischial tuberosity.

COMPOUND FRACTURES OF THE FEMUR.

Compound fractures of the femur presented by far the greatest difficulty, firstly because the patients were often severely shocked on admission to the unit, and secondly because the fractures were very difficult to reduce and immobilize.

It was often impossible to obtain anything like a perfect position, but as long as we could get reasonably good alignment we did not worry a great deal about shortening, though naturally when putting up the fracture we applied as much extension as we could.

We used the Thomas splint with skeletal traction as a routine. The extension was applied through the crest of the tibia. When the fracture was supracondylar, and the Thomas splint had to be bent to a considerable angle, the cord was taken to the end of the splint over the crossbar of a "footpiece" attached to the splint, half-way between ankle and knee, in order that the extension should act in approximately the correct line.

Immobilization.—We were under no delusion that fractures of the femur put up in this way were immobilized. It was easy to fix the lower fragment, but impossible to control movements of the upper fragment produced by the jolting of travel over rough roads, the reason being that an old surgical principle is not observed—that, although the joint below the fracture is controlled, the joint above it is not. To overcome this difficulty, we attempted to put up several fractured femurs in plaster spicas, but the results were not very satisfactory, because we had no orthopædic table or distraction apparatus.

Judging by the results of those fractures sent down by Colonel Littlejohn from Tobruk, the plaster spica appears to be the method of choice.

CONCLUDING REMARKS.

Enough has been written to illustrate the general routine of treatment of compound fractures in a casualty clearing station, though, of course, each individual fracture was dealt with on its own merits, and obviously any generalization cannot be expected to cover all cases.

We were able to follow up a proportion of the patients by taking every opportunity to visit the various general hospitals, but this follow-up was by no means complete. I am able to speak therefore only about the treatment of these compound fractures in their early stages, and cannot give a complete

picture of end results. Inquiries from the patients themselves in the general hospitals was our way of finding out which methods of treatment proved most comfortable from the patient's point of view. We had a working agreement with the various surgeons in the Australian general hospitals that they would inform us of any cases that went wrong after the patients left the casualty clearing station and any criticism of the methods employed.

We reached the conclusion that the results were good. We were able to establish the fact that no single patient developed gas gangrene after arrival at the casualty clearing station or at any later date.

In conclusion, I hope that this short paper may prove of some interest from a general point of view, and of some practical value as a guide to those to whom falls the treatment of battle casualties in the field.

BLOOD SUPPLY OF THE DISTAL COLON.[1]

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ALTHOUGH an accurate knowledge of the anatomy of the distal portion of the colon is of more than academic interest, the information on this subject which is available in current texts is lacking in essential details. Especially is this so in regard to the arterial supply to this segment of the gut, while references to Sudeck's critical point show that this term is often incorrectly used and that the vascular arrangement in this region is given a varied significance by different authors.

The distribution of the inferior mesenteric artery has therefore been reinvestigated mainly to determine whether or not the so-called last sigmoid branch anastomoses with the superior hæmorrhoidal artery; if it does, whether this anastomosis is free or poor, and whether the findings have any bearing on surgical procedures on this segment of the gut. In this paper the term "distal colon" refers to that portion of the bowel extending from the splenic flexure to the rectal ampulla.

LITERATURE.

The gross anatomy of the inferior mesenteric artery is only briefly outlined in textbooks of anatomy. This, together with a lack of uniformity in description, is probably due to the many variations which are encountered when the vascular pattern is studied. The following have been selected as representative descriptions of this artery. Others differ in no great detail from them.

In "Morris's Treatise on Anatomy" (page 602) the branches of the inferior mesenteric artery are described as the left colic, sigmoid and superior hæmorrhoidal. The left colic divides into two branches, the upper anastomosing with the middle colic, whilst the descending enters the sigmoid mesocolon and anastomoses with the ascending branch of the sigmoid artery. The sigmoid artery enters the sigmoid mesocolon and divides into two branches, the upper anastomosing with the left colic, the lower with the superior hæmorrhoidal, which latter descends into the pelvis. On reaching the posterior surface of the rectum, the superior hæmorrhoidal bifurcates, one branch proceeding on either side of the gut. In the accompanying illustration (Figure 487) three sigmoid vessels are shown arising from the inferior mesenteric artery. All of these are apparently anastomosing with one another, whilst the upper member of the series anastomoses with the left colic and the lower with the superior hæmorrhoidal artery.

In "Gray's Anatomy" (page 769) the inferior mesenteric artery is described as having three branches, the superior left colic, the inferior left colic and the superior rectal. The superior left colic divides after a variable course into ascending and descending branches. The former anastomoses with the middle colic artery in the transverse mesocolon, whilst the latter anastomoses with the highest inferior left colic (sigmoid) artery. From the arches formed by these anastomoses branches are distributed to the left half of the transverse colon and to the descending colon. The inferior left colic (sigmoid) arteries, two or three in number, run to supply the lower part of the descending colon and pelvic colon, anastomosing above with the superior

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left colic artery and below with the superior rectal artery. The latter anastomosis, however, is dependent on one or more very slender connexions. The superior rectal artery (superior hæmorrhoidal) descends into the pelvis and divides opposite the third sacral vertebra to send a branch to either side of the rectum.

According to Poirier and Charpy, "*Traité d'anatomie humaine*" (page 776), the inferior mesenteric artery is distributed in the following manner. The vessel divides into two branches of equal size, the trunk of the left colic arteries and the superior hæmorrhoidal artery. The trunk of the left colic arteries enters the thickness of the pelvic mesocolon and divides into two or three branches which divide and anastomose with one another, forming, as on the right side, a series of arcades; from these arise the terminal branches which go to the left half of the transverse colon and to the descending and iliac colons. The highest of the left colics anastomoses with the middle colic artery, whilst the lowest anastomoses with the superior hæmorrhoidal artery. The middle supplies the sigmoid loop of the pelvic colon. The superior hæmorrhoidal descends in the thickness of the pelvic mesocolon and approaches the wall of the rectum. Arriving at the superior part of the rectal ampulla, it divides into two branches which spread out and descend on the sides of the rectum as far as the anus.

It is to be noted that all these authors refer to the existence of an anastomosis between the last sigmoid and superior hæmorrhoidal arteries, though the extent of this anastomosis is admitted to be variable. No indication, however, is given as to its site. Moreover, there is no reference to the site of origin of the branches from the parent trunk or to the range of variation of their number. It is also inferred that the colic and sigmoid branches take origin above the pelvic brim, whilst the main vessel continues into the pelvis as a single trunk which is called the superior hæmorrhoidal artery. Actually this is far from the condition usually revealed by dissection, as will be shown.

Drummond's (1914) account of the arterial supply to the rectum and pelvic colon, based on an examination of twenty injected specimens, is unfortunately lacking in certain details, though the illustrations of his injected specimens are excellent. He describes a left colic and up to four sigmoid branches, but there is only a brief reference to the site of origin of the sigmoid vessels and to the wide variation in their number. Concerning the nature of the anastomosis between the last sigmoid and superior hæmorrhoidal arteries, he states in one section that the sigmoid arteries "supply the lowest part of the descending colon and the iliac and pelvic colons by a series of loops which anastomose above with the lower branch of the left colic, and below with the main trunk of the superior hæmorrhoidal artery". But later, when discussing the arcades formed by the sigmoid arteries, he states that "the lowest sigmoid branch does not form an anastomosis with the superior hæmorrhoidal artery in this arcade fashion". This make it difficult to interpret his findings on this point.

INVESTIGATION.

In this investigation twenty-five specimens were examined. The arterial distribution of the inferior mesenteric artery was traced by dissection in twenty dissecting-room subjects. In five post-mortem subjects, in which the entire distal colon had been stripped from the posterior abdominal wall without damage to its vascular supply, the main vessel was injected with a radio-opaque material and the arterial pattern was photographed by X rays.

The following information was obtained:

1. The inferior mesenteric artery invariably supplied the bowel from the splenic flexure to the rectal ampulla, just above the *levator ani*, where the terminal branches were seen entering the muscle coat.

2. The inferior mesenteric artery constantly took origin from the left antero-lateral aspect of the abdominal aorta within the limits customarily given, namely, three to four centimetres above the bifurcation of the aorta.

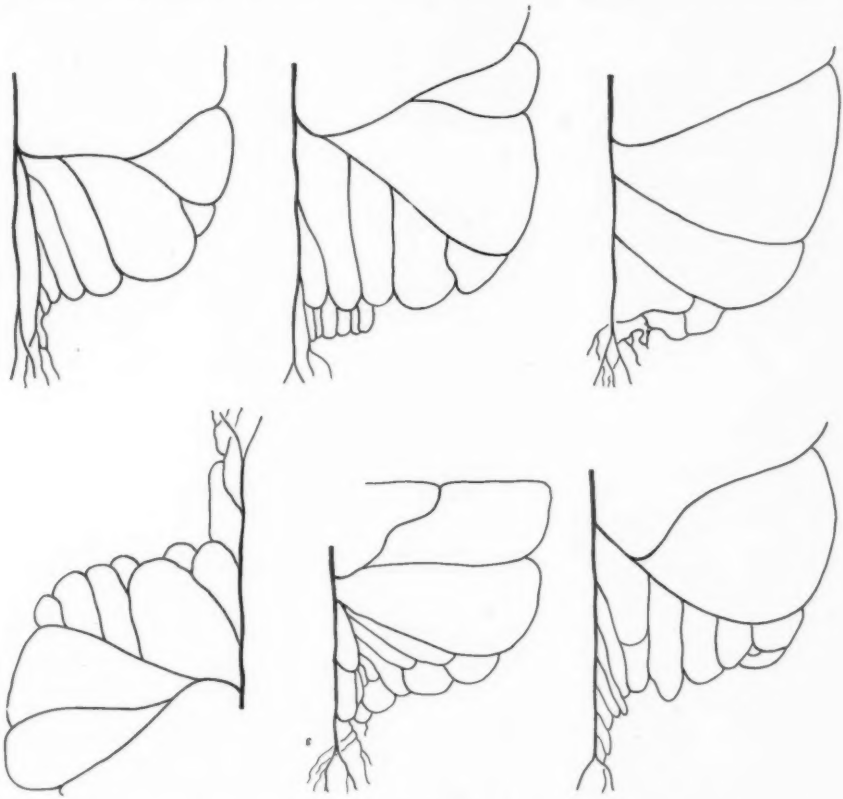

FIGURE I. Diagrammatic representation of patterns of the inferior mesenteric artery to illustrate some of the variations observed.

3. The terminal part of the main mesenteric trunk bifurcated into two branches of approximately the same size. It is proposed to call these branches the superior hæmorrhoidal arteries. The site of this bifurcation varied (see later).

4. The two terminal branches of the inferior mesenteric trunk invariably branched and rebranched into vessels which continued down the walls of the rectum to penetrate, finally, its muscle coat at the ampulla.

5. The last branch (usually called lowest colic or sigmoid) of the inferior mesenteric artery, before the latter vessel divided into the two superior hæmorrhoidal arteries, always descended vertically to reach the rectum, over the proximal portion of which it spread its terminal branches.

6. The terminal branches of this lowest colic branch overlapped, to a variable degree, the field of distribution of the superior hæmorrhoidals (see Figure II).

7. Without exception there was a well-marked anastomosis between all colic branches, so that a continuous vascular arcade extended along the gut wall as far as approximately the recto-sigmoid junction, beyond which it was carried as a descending terminal colic vessel to the proximal rectum.

8. In this series the terminal loop between the lowest two colics was always well marked. Thus Drummond's observation that "the last sigmoid branch of the inferior mesenteric not only varies considerably in size, but that it has an erratic communication with the sigmoid branch above" was not confirmed. Reference to the significance of the terminal arcade linking the lowest two colic branches will be made later.

9. Any supply to the rectum from the hypogastric artery was small and appeared to be of no consequence. This is in agreement with Drummond's observations.

10. No other arteries supplied the rectum above the *levator ani*.

The following variations were observed:

1. The number of branches given off from the main inferior mesenteric trunk varied from one to seven.

2. Both the site of origin and the manner of distribution of the branches were irregular and did not permit the construction of any definite or constant arterial pattern. Examples of the variations observed are illustrated in Figure I.

3. Branches were observed to take origin in the following regions: before the parent trunk crossed the common iliac artery, while it was running in the interspace between the two common iliac vessels, and in the sacral hollow. In four out of twenty-five cases the last branch took origin from the main trunk within half an inch of its division into the superior hæmorrhoidal arteries.

4. The site of the terminal division of the inferior mesenteric artery into the two superior hæmorrhoidal arteries varied from the first to the third pieces of sacrum, and this point of bifurcation bore no relation to the site of the pelvi-rectal junction.

5. When the number of branches was limited to one, two or three, these vessels maintained the blood supply along the entire distal colon by means of large collateral branches (see Figure II). In the majority of cases only one arcade was formed which was always in contact with the bowel wall. Occasionally the larger branches were linked more proximally by anastomosing channels, so that in some areas arcades of more than one degree were formed (see Figure III).

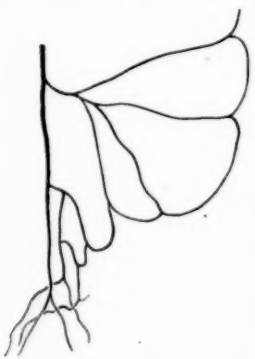

FIGURE II. Diagrammatic representation of a pattern in which only two colic arteries were given off from the main inferior mesenteric trunk to supply the distal colon by large collateral branches.

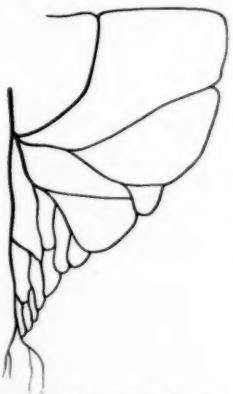

FIGURE III. Vascular pattern showing the formation of multiple arcades. In this specimen the lowest colic branch anastomosed with the left superior hæmorrhoidal artery.

6. The formation of secondary and tertiary arcades was not, however, common, and appeared to depend to some extent on the degree of development of the sigmoid mesocolon.

7. Although the branches of the lowest colic artery overlapped to a variable degree the field of distribution of the superior hæmorrhoidals, in only five of twenty-five cases examined did the former anastomose with one or other of the superior hæmorrhoidal arteries as illustrated in Figure III.

8. In three cases the inferior mesenteric artery gave origin to the middle colic artery, but in all the specimens the anastomosis between the highest left colic and middle colic arteries was large, the vessels showing little diminution in size along their course.

Conclusions.

This investigation into the vascular pattern of the inferior mesenteric artery has demonstrated that:

1. A great variation in the number of colic branches given off from the inferior mesenteric artery is a characteristic and important feature of the vascular pattern.

2. These branches may take origin from any point along the course of the parent vessel between the site of its origin from the aorta and a point immediately above its terminal bifurcation into the superior hæmorrhoidal arteries.

3. In the majority of cases no anastomosis between the last colic and superior hæmorrhoidal arteries takes place outside the bowel wall and so no reliance can be placed on the possibility of the existence of such an anastomosis.

4. The anastomoses between the branches of the inferior mesenteric artery before its terminal division are, on the other hand, constant.

5. Contrary to Drummond's observation, the terminal arcade between the lowest two colic arteries is well established.

6. The field of arterial distribution of the lowest colic overlaps, in a varying degree, that of the superior hæmorrhoidal arteries.

7. The terminology in current use is open to criticism. The upper branches of the main artery could be called colic and the lower sigmoid. In many cases, however, the so-called sigmoid arteries were given off deep in the sacral hollow and supplied only the distal portion of the sigmoid colon, as well as the upper part of the rectum, while the proximal and middle parts of the sigmoid colon were supplied by descending branches from the higher colic vessels. The arrangement of the branches of the inferior mesenteric artery is so irregular and bears so little relationship to the arbitrary division of the distal colon into its several parts that it would be more correct to name all branches left colic arteries. It is also suggested that, since the main trunk frequently gives origin to many sigmoid branches after it has crossed the pelvic brim, the term superior hæmorrhoidal should be restricted to the two terminal branches into which the inferior mesenteric artery bifurcates. The nomenclature in current use is quite meaningless instead of being self-explanatory.

Discussion.

To avoid any confusion concerning the site and nature of Sudeck's critical point it may be stated that direct reference to Sudeck's original paper on this subject has shown that his "*kritischer Punkt*" is the point of origin of the lowest colic vessel which anastomoses with the colic branch immediately above it in the pattern. The clinical significance of this critical point in determining the site of division of the inferior mesenteric artery in

resections of the pelvic colon and rectum will now be examined. It is important to appreciate, as a basis for further discussion, that the principles involved are not quite the same in the two cases. Failure to observe this difference has been responsible for much of the confusion concerning the significance of the critical point. For instance, if the main trunk of the inferior mesenteric artery must be interrupted in resection of the pelvic colon, the site chosen for its division should be such as to ensure an efficient blood supply reaching the sigmoid stump. In perineal excision of the rectum with restoration of function, however, division of the artery is undertaken primarily to facilitate mobilization of the gut, the site of division being so chosen as to preserve an adequate blood supply to that portion of the bowel which is brought down to the perineum. If, however, the resection of the rectum is to include portion of the sigmoid colon, it is obviously only necessary to ensure that the portion of the mobile (sigmoid) colon brought out as an end colostomy should have an adequate blood supply and this is assured by the constant presence of an arcade along the bowel wall. For the sake of convenience and in order to avoid confusion, it is therefore proposed to consider, as an anatomical problem, the significance of the arterial pattern and critical point in terms of the surgery of the colon and of the surgery of the rectum.

Surgery of the Pelvic Colon.

The following references to the significance of the vascular pattern in the surgery of the pelvic colon will illustrate the lack of precision and essential detail found in the literature.

In "Gray's Anatomy" (page 771) there is the following statement:

> As a result of the free anastomoses between the left colic arteries a continuous "marginal artery" descends near the gut from the left colic flexure to the distal end of the pelvic colon, where it stops, because the superior rectal artery does not divide into arch-forming branches. The point where the lowest left colic artery anastomoses with the superior rectal artery is therefore sometimes named the "critical point". Ligature of these two arteries will almost certainly result in gangrene of the part of the rectum which is supplied by them. If, however, the inferior mesenteric artery be tied proximal to the origin of its lowest colic branch, blood can pass through the latter branch into the superior rectal artery.

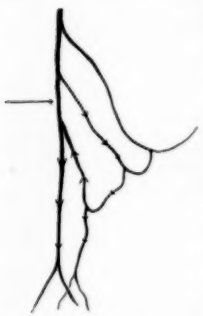

FIGURE IV.

The course along which the flow is redirected is indicated in Figure IV. Here the critical point differs from that described by Sudeck, while it is also to be noted that the lowest colic branch is stated to anastomose with the superior rectal artery, which leaves the functional significance of the vascular pattern uncertain. Concern is here expressed for the nutrition of the rectum, and from the information given it is evidently to be inferred that there is no significant collateral circulation established from the inferior hæmorrhoidal arteries.

McGregor, however, gives a different interpretation to the arrangement when he states that

> . . . the anastomosis between the superior hæmorrhoidal and the lowest sigmoid artery is very poor. In excision of the pelvic colon for cancer, the inferior mesenteric must be divided above the origin of the last sigmoid or gangrene of the rectum may occur.

Accompanying this statement is a diagram (Figure 47) illustrating the direction of flow taken by the blood following the ligation which is the reverse of that expressed in the previous section. Thus the blood is directed from collateral channels back along the superior hæmorrhoidal to the inferior mesenteric trunk, and then by way of its lowest colic branch to the distal

part of the sigmoid colon as far as the site of transection (see Figure V). It is also to be noted that in Figures 46 and 47 in McGregor's book the site given for Sudeck's critical point is incorrect.

In both circumstances there is no reference to the nature and extent of the resection. It is generally recognized that, whenever possible, the main trunk of the inferior mesenteric artery and its lowest colic branch should be carefully preserved so that the rectum and recto-sigmoid junction will be adequately supplied. In what circumstances the inferior mesenteric artery would require ligation in resection of the pelvic colon is not clear; but assuming, as is indicated in the statements quoted, the section to involve division of the inferior mesenteric artery, then blood is prevented from reaching, by way of the main trunk, that part of the bowel which is supplied below the site of ligation. In such a case the site of election for division of the artery would be as indicated in both the statements quoted, though the direction in which the collateral circulation would be established is that illustrated by McGregor for the following reasons. The blood supply to the recto-sigmoid junction and rectum has been shown to be from the last colic and superior hæmorrhoidal arteries, the former overlapping the field of distribution of the latter for a variable distance. Between these two sets of vessels, however, there is little, if any, anastomosis, so that if blood is to reach the lowest colic artery (sigmoid) from the superior hæmorrhoidals (there is no other route open because the arcade along the bowel wall has been interrupted in the resection), it must do so in a retrograde manner via the main inferior mesenteric trunk. The only effective supply to the superior hæmorrhoidals in such cases appears to be from the inferior hæmorrhoidals, for the middle sacral artery rarely, if ever, sends branches to the rectum and any contribution by the middle hæmorrhoidals appears to be small and of no consequence. To permit the establishment of such a collateral circulation the inferior mesenteric artery must be divided no lower than the site indicated. How effective such a collateral supply would be functionally and how far it could ascend the gut are doubtful, but experience suggests that it would hardly supply the gut effectively as high as the lower sigmoid colon. An examination of the arrangement of the vessels and the source of the collateral circulation shows that the portion of the gut which is most certainly threatened is not the rectum, as stated, since this stands a far better chance of survival, but that portion of the sigmoid colon immediately adjacent to the recto-sigmoid junction which is supplied solely by branches of the lowest colic artery. If the collateral supply is to come from below, then the sigmoid stump should be short. Even in these circumstances the vitality of the sigmoid stump cannot be guaranteed because of the uncertainty of the collateral supply from the inferior hæmorrhoidal arteries.

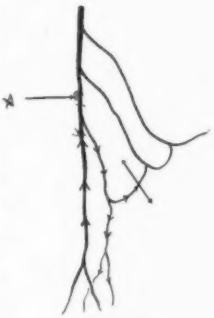

FIGURE V.

The site of division of the inferior mesenteric artery is not the only feature of importance in connexion with resections of the pelvic colon, though it appears to have received most attention. Of more importance are the site and direction taken by the distal line of resection in relation to the descending lowest colic artery, irrespective of whether the inferior mesenteric artery is ligated or preserved. The significance of this relationship will be appreciated by studying the vascular arrangement, diagrammatically represented in Figure VI, where the terminal arcade is present and efficient, and the lowest colic artery descends to supply the terminal portion of the sigmoid colon and the recto-sigmoid junction, and to overlap for a short

distance the field of supply of the superior hæmorrhoidal arteries. No anastomosis is present between the lowest colic vessel and either superior hæmorrhoidal. It is immaterial, under the conditions to be outlined, whether the inferior mesenteric trunk is divided at A, the site advocated to ensure that blood reaches the lowest colic from below, or whether the main trunk is preserved, as is usually the case, in order to allow blood to reach it from above. If the line of resection is directed along Y—that is, across or above the terminal arterial arcade—and if the main stem of the lowest colic branch proximal to the arcade is preserved, then blood can reach the proximal portion of the distal gut segment by way of the intact lowest colic artery. If, however, the line of resection is inadvertently carried across the gut and vessels along the line X, thus dividing the lowest colic artery as illustrated, or, alternately, if the lowest colic artery were ligated at its origin during the resection, then that portion of the gut supplied by the vessel, namely, the sigmoid stump, would be deprived of its blood supply. It is therefore important to remember that the lowest colic vessel should never be ligated at its origin, while, in order to avoid cutting across the course of the vessel, the distal line of resection should never pass below the terminal efficient vascular arcade. Usually the descending lowest colic is located deep in the sacral hollow, and so is adequately protected (see Figure I, sixth diagram); but this is not always the case, as is well shown in the specimen illustrated in Figure VII where the sigmoid colon is supplied by a very long descending lowest colic artery. It will be readily appreciated from the vascular arrangement present in this case that if the line of transection crossed the pattern at *a*, then that portion of the gut supplied by the pattern below *a* would be deprived of its blood supply. The importance of the entire pattern, and not just one particular portion of it, is therefore well illustrated and emphasizes the need for a careful survey of the pattern prior to the division of any vessel or the selection of the line for resection. This case also illustrates the impossibility of dividing the main trunk of the artery above its last colic branch, the site advocated when division is demanded, without impairing the blood supply to the entire distal colon.

FIGURE VI. A diagram illustrating the effects of damage to the lowest colic artery. The stippled area is that deprived of its blood supply when the vessel is damaged by the line of resection X.

The following conclusions have been drawn from these observations:

1. The main trunk of the inferior mesenteric artery should be carefully preserved in order to maintain an efficient supply to the rectum and that portion of the sigmoid colon left attached to it.

2. It is imperative, in view of the absence of a reliable anastomosis between the descending lowest colic and superior hæmorrhoidal vessels, that the former vessel should be carefully preserved

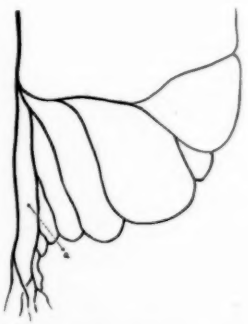

FIGURE VII. The arterial pattern in a specimen in which the inferior mesenteric artery gave origin, at the same point, to two colic branches only. If the pattern is interrupted along the line *a*, then that part of the bowel supplied by the last descending colic artery, below the site of division, can no longer receive blood.

throughout its course in order to maintain the proper nutrition of the sigmoid stump and recto-sigmoid junction.

3. Before the line of resection is chosen, or any vessel divided, as much of the vascular pattern as can reasonably be explored should be examined, the variations and significance of the pattern and the consequences which follow damage to any vital arterial channels being well kept in mind.

4. When the main trunk of the inferior mesenteric artery must be interrupted, though this should rarely be necessary, the most distal site possible for its division, in order to circumvent the critical point, is between the origins of the lowest two colic branches. The route along which the collateral circulation is established, is from the inferior to the superior hæmorrhoidal arteries, and then by way of the inferior mesenteric trunk to the lowest colic artery. This enables blood to reach not only the rectum proper, which is supplied directly from the superior hæmorrhoidals, but also that part of the bowel about the recto-sigmoid junction, supplied by the lowest colic artery, which cannot receive blood from above, because of the interruption of the arcade system by the resection, or directly from the superior hæmorrhoidals because of the absence of an anastomosis between the lowest colic and superior hæmorrhoidal arteries. How high this collateral circulation can effectively supply the sigmoid colon is uncertain, but for reasons set out in this paper it is suggested that the sigmoid stump left attached to the rectum and supplied by the lowest colic artery should, in these circumstances, be left as short as possible.

5. In the selection of the site for ligation the extreme variation in the number and site of origin of the colic arteries is to be remembered and the site of division modified accordingly.

Surgery of the Rectum.

In connexion with the surgery of the rectum the original observations of Hartmann on the significance of the critical point demand special consideration. Referring to perineal amputation of the rectum, Hartmann writes:

> It is not rare to see in such cases, once the prerectal peritoneal cul-de-sac has been opened, the rectosigmoid portion present itself and permit itself to be easily drawn down, while the rectum proper, especially its ampullary portion, remains fixed, being held firmly by the superior hæmorrhoidal branches which descend in a straight line from the aorta. In order to make possible the coming down of this portion of the intestine, it is absolutely necessary to cut the superior hæmorrhoidal vessels. It is then easy to draw the rectum outside, but as far as can be seen, there develops a consecutive gangrene the pathogeny of which is explained by the anatomy of the vascular system of the region. . . .

Concerning this vascular system he continues:

> The results of these researches, in great part confirmative of those published two years ago by Sudeck (*Muench. med. Woch.*, 1907, pp. 13, 14), are that if the operator wishes to have an intestine which may be brought down to the level of the skin of the perineum without traction and still well nourished, it is necessary to avoid cutting the hæmorrhoidal arteries at the point where one is led necessarily to divide them when working exclusively from the perineum. It is necessary to place a ligature high up on the common trunk of these arteries above the last anastomotic loop which, as we have said, is found a little lower than the promontory, and it is necessary to tie both ends, the blood flowing back in abundance by the inferior end.

It is important to recognize that the particular operation under consideration is specifically stated to be perineal amputation of the rectum in which the intestine is brought down to the perineum, and that the inferior mesenteric trunk is divided in these cases to facilitate mobilization of the ampullary portion of the rectum, and at the same time to preserve an adequate blood supply to the distal segment of the gut brought down. To accomplish this the main arterial trunk must be divided no lower than between the origins of the lowest two colics, which form an efficient arcade, because

the descending lowest colic artery does not pass sufficiently far down the bowel wall to maintain the nutrition of the lower end of the proximal segment, particularly when the gut is under traction. This is well illustrated in Figure VIII. In the diagram accompanying Hartmann's paper the lowest colic is not illustrated descending to reach the rectum, an observation not confirmed in this investigation, so that in such circumstances there would be even more reason to preserve a collateral supply through the arcade system to the lower segment of the inferior mesenteric and superior hæmorrhoidals.

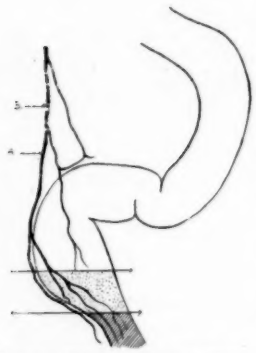

FIGURE VIII. Diagram illustrating the effect of ligating the inferior mesenteric artery at A, below the last anastomotic branch, and at B, above the last anastomotic branch, in perineal excision of the rectum. The shaded area represents the proximal portion of the rectum excised. The dotted area represents the distal end of the proximal bowel segment which is left without an arterial supply when the inferior mesenteric artery is divided at A, but which can receive blood when the ligation is performed at the site B or at a more proximal level.

Thus division of the inferior mesenteric artery is demanded to facilitate effective mobilization of the gut. The site of election for ligation and division is between or above the origins of the lowest two colic branches linked by an efficient arcade so that blood may reach the main trunk below the site of division as indicated in Figure IV. This is the direction of flow outlined in "Gray's Anatomy", so that the reference to the critical point in that text now appears in its correct setting. Smith and Drummond have also drawn attention to the importance of Hartmann's observations on the significance of the vascular pattern in rectal surgery.

In connexion with the site selected for ligation and division one additional point merits close attention. It will be appreciated from the great range of variation of the vascular pattern recorded in this paper how difficult it would be on most occasions to identify the site of ligation recommended and to deal with it from below. For instance, taking again the pattern in which only two branches took origin from the inferior mesenteric artery, and these at the same point, it will be appreciated how impossible it would be to ligate and divide the inferior mesenteric artery above the point of origin of its lowest colic branch, let alone to reach that point from the perineum. Because of the importance of the critical point in determining the site of ligation, Sudeck advocated exploration of the pattern by the abdominal route in order to locate the exact site of the critical point. One can do no better than to emphasize this feature and stress the need for a careful scrutiny of the pattern before dividing any vessel.

Drummond has reported that the arcade between the lowest two colic vessels is variable in its presence. It is upon this arcade that the establishment of the main circulation would be thrown if the inferior mesenteric trunk were divided between the origins of the lowest two colic branches, so that his observations are of particular importance. In his twenty cases the arcade in question was absent in two, insignificant in eight and well marked in ten. On account of this variation he advocates that the site of ligation should be shifted higher up the trunk between the branches which form a well-marked arcade. He recommends division below the first sigmoid branch. Though this variation in the arcade linking the lowest two colic vessels was not confirmed in this investigation, it would be wise, in view of the small series (twenty-five) examined, to refrain from expressing a dogmatic opinion on the nature of the terminal arcade and to play for

safety by ligating and dividing the main vessel at a higher level. Moreover, it will often be found more convenient to divide the trunk at a higher level because the terminal arcades are frequently situated deep in the sacral hollow. Again, the presence of marked deposits of fat and the nature of the incision may prevent the exploration of the lower limits of the pattern.

The conclusions based on these observations may be conveniently summarized as follows:

1. The inferior mesenteric trunk is doubly ligated and divided to facilitate effective mobilization of the ampullary portion of the rectum and at the same time to preserve the vitality of the distal segment of the gut brought down to the perineum.

2. The site of ligation should be between or above the origins of the lowest two colic branches which are linked by a well-developed arcade, for it is along this arcade that the main circulation is established.

3. In view of possible variations in the degree of development of the arcade between the lowest two colic branches, the inferior mesenteric artery should be divided at a higher level than between the lowest two colic vessels.

4. The site of election for ligation is to be determined by the abdominal route after a careful examination of the arterial pattern.

5. The operation to which these remarks apply is a perineal amputation of the rectum in which the gut is brought down to the perineum with restoration of function.

SUMMARY.

1. An investigation into the pattern of the inferior mesenteric artery and the blood supply to the distal colon is described.

2. The literature relating to the presence and significance of the "critical point" is briefly reviewed.

3. Because it is so infrequent, no reliance can be placed upon the existence of an anastomosis between the lowest left colic and superior hæmorrhoidal vessels.

4. The vascular distribution is discussed in terms of the part it plays in the surgery of the pelvic colon and rectum. The importance of the vascular pattern is emphasized in that it (*a*) preserves the vitality of the recto-sigmoid stump in resection of the pelvic colon, (*b*) permits effective mobilization of the gut in perineal excision of the rectum with restoration of function.

ACKNOWLEDGEMENT.

I wish to express my thanks to Mr. Henry Searby, F.R.C.S., for many helpful suggestions made in connexion with the preparation of this paper for publication.

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A NOTE ON THE MORPHOLOGY OF THE GALL-BLADDER.[1]

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JUDGING from the enormous number of cholecystectomies which have been carried out without apparent detriment to the patients, it would seem that the gall-bladder in man can have little value in the make-up of the organism. As a result of this, it has come about that the gall-bladder is often removed with little reason. Cholecystectomy, however, is not so free from ill consequences as is thought, and authorities could be quoted to show that this operation is followed by ill effects in a proportion of cases.

In the light of this knowledge, it is my purpose in this note to discuss morphological reasons for existence of the gall-bladder in man, in an endeavour to find out what part it plays in the organisms.

The first record of any interest being taken in the morphology of the gall-bladder appears in the "Edwin Smith Surgical Papyrus" of 2000 B.C. Here the situation, size and degree of distension were used in divinations. In the old Jewish Talmudic law it was laid down that any animal which had no gall-bladder, or two gall-bladders, was *"terefah"*, or forbidden as food. Further evidence of an active working knowledge of the variations of the anatomy of the gall-bladder in the same species is shown by the fact that no species of birds was called *"terefah"* as long as the whole species exhibited such absence or abnormality. Thus the dove and the pigeon were not *"terefah"*, since none of the species had gall-bladders.

Galen recognized the collecting functions of the gall-bladder, and may even have noticed gall-stones.

Areté Dé Coppadoce, who was one of the most well-known writers of antiquity, and who lived in the reign of Domitian, believed that the liver formed blood and that bile was formed in the gall-bladder.

Early in the thirteenth century, Kimbi noticed that some animals, such as the dog, quail and canary, had gall-bladders on their intestines. He also added, however, that whereas some animals had gall-bladders in their bellies, some had them in their ears!

Exact knowledge was made available by Francis Glisson in *"Anatomia Hepatis"*, published in 1654.

The gall-bladder fills by virtue of the diversion of bile from the intestine. The sphincter of Oddi at the junction of the common bile duct and duodenum is closed for most of the time, being open only when gastric contents are passing into the duodenum. Bile having entered the gall-bladder, the gall-bladder now performs its most important function, that of storage. Since its actual volume as a reservoir is only about thirty-five cubic centimetres, it performs this function by concentrating the bile about ten times. This function depends on the integrity of the wall, so that the ability of the gall-bladder to store bile is greatly impaired by gall-bladder disease. The mucosa of the gall-bladder secretes a small amount of mucus, and thus if the neck of a functioning gall-bladder is obstructed for some time a mucocele of the gall-bladder results (in the absence of infection).

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The mechanism by which the gall-bladder empties is not quite decided. It is generally accepted that its emptying is brought about in man by definite muscular contractions of its wall. It is difficult, however, to see how this mechanism can be effective in the case of some of the monkeys, where the gall-bladder is completely imbedded in the liver. There is some doubt as to how the wall of the gall-bladder is stimulated to these contractions. Recent observations suggest that there is little or no nervous influence in the mechanism of contraction, as was formerly thought, but that a hormone, cholecystokinin, is liberated by the passage of certain foods into the duodenum. This substance has been shown by crossed circulation experiments to be a true hormone. It can be extracted from the mucosa of the upper part of the intestinal tract.

With the object of obtaining information in regard to the *raison d'être* of the gall-bladder, its morphology was studied in different species of animals and birds. In all, about 44 different species were dissected. Further, most of the dissections of native animals in the Canberra Anatomy Museum, showing the gall-bladder, were examined and drawn. Use was also made of personal communications from and drawings of dissections made available by Professor Wood Jones. The structure of the gall-bladder in those animals not available for dissection was studied through the literature.

In general, those animals which may be said to be least "specialized"—that is, which are lowest on the evolutionary scale—have gall-bladders; and animals, such as frogs, lizards *et cetera*, have a large gall-bladder; indeed, the gall-bladder in the frog is an almost vital organ.

The importance of the gall-bladder in animals like the frog was shown by the following simple experiments. Four frogs of the same species were subjected to laparotomy, and in two the neck of the gall-bladder was tied off with thread. On the fourth day after the operations, the frogs were fed with a fatty meal and on the following day they were killed and examined. In the intestines of those frogs which had had no interference to their biliary system, very little of the fatty meal remained undigested; but in the intestines of the frogs that had had their cystic ducts tied off the fatty meal remained practically unaltered. In these two cases, mucocele of the gall-bladder was present as a result of the ligation of the cystic duct. This simple experiment indicates the importance of a gall-bladder in animals low in the evolutionary scale.

Those animals which are lowest on the scale of mammals, such as the platypus and echidna (monotremes), and animals such as the kangaroo, wallaby *et cetera* (marsupials), have very large gall-bladders.

Nearly all carnivorous animals have well developed gall-bladders. This is to be expected, for they feed at irregular intervals on food which contains large quantities of fat; and thus they require large quantities of bile at a time to emulsify this fat. In this carnivorous group of flesh-eating animals are the insectivora, such as the hedgehog.

In contrast to the carnivores, herbivorous animals which have to digest finely divided food have, in general, lost their gall-bladders. Thus the horse, elephant, antelope, male giraffe and camel have no gall-bladders. The gall-bladder too is absent from all the deer, except *Moschus*—the smallest and most primitive of the species.

The above simple generalization is open to many exceptions.

It is difficult to see why the African ostrich should be without a gall-bladder, while the Australian emu has one; and why the three-toed sloth has no gall-bladder, and the two-toed sloth has one.

Of special interest among the exceptions are the Artiodactyles (an example of which is the cow), which are without gall-bladders. These are a sharp

contrast to the Perissadactyles (an example of which is the horse), which have very similar feeding habits. A possible explanation is that the Perissadactyles have lophodont teeth, and that they graze and crop the grass finely with a lawnmower-like action, while the Artiodactyles, on the other hand, have sphenodont teeth and pull up the grass in bunches (roughly divided food) rather than crop it, and are, on the whole, ruminating animals. The antelopes, camels and Cervidæ are, however, "true to form" and do not have gall-bladders.

It is difficult to explain why rats have gall-bladders and mice, as a rule, have no gall-bladder; or why the male giraffe has no gall-bladder and the female may have one.

As has been pointed out, animals which crop their food and which therefore have a means of converting a discontinuous food supply to a continuous one, do not as a rule have a gall-bladder. But an exception to this is *Spalax*, which is a rodent with the habits of a mole, and which has a large functioning gall-bladder.

Marsupials with somewhat similar feeding habits have gall-bladders, and most rodents have none. This, as pointed out, may be a question of the lowness in the scale of evolution of the marsupials.

Geographical distribution can apparently play no part in the determination of whether an animal has a gall-bladder, for the Indian elephant and the American three-toed sloth are without gall-bladders.

In birds there appears to be difficulty in attributing any factor or factors for the presence or absence of gall-bladders. Most birds that are carnivorous have a gall-bladder. Parrots and humming birds have no gall-bladder. Pigeons and cuckoos occasionally have gall-bladders. The emu and the cassowary have gall-bladders.

It is not impossible that the feeding habits of birds may have something to do with the presence of a gall-bladder. For instance, curlews and sandpipers feed at intervals and have gall-bladders. These birds feed on worms at early morning and late at night, the feeding time being dependent on the state of the tide, since these worms are exposed only when the tide is at ebb. The mutton bird eats crabs; the Pacific gull, silver gull, shag, sandpiper and green finch feed on crustaceans and shell fish; and all these birds, therefore, feed at intervals because they are dependent on the tide for their food, and all have gall-bladders.

In the following table the presence or absence of a gall-bladder can be compared in some families of birds.

Present.	*Absent.*
Grus (occasionally absent).	Trochilidæ (humming birds, 581 species).
Mergus (occasionally absent).	Psittaci (parrots *et cetera*; sometimes present in cockatoos).
Tringa (knots and sandpipers).	Columbidæ (sometimes present in pigeons).
Curlews, gulls, mutton birds.	Cuculidæ (occasionally present).
Dotterel.	*Struthio.*
Emu and cassowary.	*Numida* (guinea fowls, 23 species).
Raptores.	*Rhea* (occasionally present).
Insessores.	
Natatores.	
Rasores (except doves, which have short caeca and are vegetable eaters).	

Thus there may be some evidence that those animals which are low in the evolutionary scale, or which have irregular and infrequent feeding times, require a gall-bladder; and that those animals which are high in the evolutionary scale, or have a continuous supply of food and lay in fat, do not require a gall-bladder. To these very broad generalizations, however, it must be noted that there are many exceptions.

It may be that some inference in relation to the gall-bladder in man may be drawn from these observations in animals. In man one would expect (in the absence of errors in technique) that, following cholecystectomy, the patient would be better off on frequent small meals; that is, on an almost continuous supply of food and on a diet low in fats. With these precautions one would expect that no morbidity should follow in the wake of cholecystectomy, for man is a highly specialized animal on a mixed diet.

Since the gall-bladder in some lower animals is an essential organ of digestion, and many animals which do not eat fleshy food and which have more or less continuous feeding as a characteristic of the species, do not require a gall-bladder, one would expect that in man the removal of the gall-bladder would be followed by little disturbance. Probably, where it is followed by morbidity, this is due to minor injuries to the common bile duct, to spasm of the sphincter of Oddi, or even to the non-appearance of the usual post-cholecystectomy hypotonus of this sphincter.

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EXPERIMENTAL STUDIES IN THE USE OF AMNIOPLASTIN.[1]

By J. D. Hicks, E. R. Trethewie and Eleanor Williams.[2]

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Introduction.

Yi-cheng Chao, Storer Humphreys and Wilder Penfield (1940) have suggested the use of amniotic membrane (amnioplastin) to replace gaps in the *dura mater* following such trauma as occurs in compound fractures and excision of the dura in operations on cerebral tumours. They have performed numerous experiments on cats in which the cortex was injured by pin pricks and in some cases sliced deeply, and found that when amnioplastin (always boiled before use) was used to replace excised dura, adhesions between reformed dura and cortex did not appear.

In experiments upon dogs we have tested amniotic membrane prepared in a similar manner, but sterilized by dry heat. In view of Penfield's further publication (1940), reporting the development of adhesions if dry membrane was used, the membrane in a second series of experiments was boiled as advised by him. Since it was suggested that the development of adhesions might be due to contained fat, defatted membrane was also tested and microscopic sections of the lesions were stained for fat.

Methods.

Amniotic membrane was stripped from human placentæ within one to two hours of delivery, and it was then washed in water. The membrane was placed in 60% alcohol for periods up to twenty-four hours; it was then spread on porcelain and the mucus was scraped off with a blunt wooden instrument. The cleaned membrane was stretched over embroidery hoops and allowed to dry in the air. The dry material was cut into sheets, each of which was placed between two layers of gauze and packed in wrappers of special paper. These were sterilized at 160° C. for one hour by dry heat, being kept flat by heavy glass plates.

In some cases fat was removed from membranes by stirring them in absolute alcohol for ten minutes, allowing them to dry in the air and then placing them in a vacuum desiccator.

In dogs under chloroform anæsthesia a hemi-elliptical incision was made through the scalp and the left parietal, part of the right parietal and left frontal bones, and the left temporal muscle were exposed. The muscle was removed from its origin, and the parietal bone trephined and nibbled away over an oval area approximately 6 by 4 centimetres. The dura was removed over a triangular area 2 by 3 by 3 centimetres, or a four-sided figure the sides measuring from 1·5 to 3·0 centimetres. The cortex was then injured by making six superficial wounds, three millimetres long and one to two millimetres deep, with scissors. Clotting was encouraged under a layer of cotton wool, which was removed, though occasionally muscle had to be used in addition to stop

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bleeding. Membrane was then placed over the deficiency and the temporal muscle was replaced by stitches uniting it to the pericranium and loose tissue in the mid-line.

RESULTS.

The Formation of Adhesions when no Membrane was Introduced to Cover the Deficiency in the Dura.

At the end of two weeks moderately firm adhesions were found between the under surface of the temporal muscle and the cortex in the situation of all six wounds.

After five and a half weeks the adhesions were tougher and some were vascularized. The deficiency in the dura was completely replaced by new

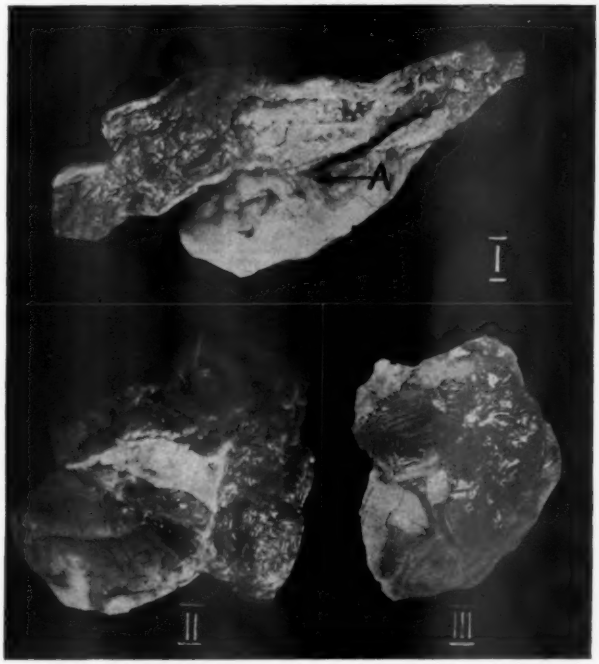

FIGURE I. Specimens of brain and dura: I and II, three months after operation; and III, five months after operation. No membrane was used. Details in text.

membrane which was adherent to the temporal muscle. One dog in this series died after three months from the original operation, three epileptiform fits having occurred, death supervening six hours after the onset of the first fit. In this animal adhesions were very well marked, especially anteriorly and medially (see Figure I—I, II). On the medial side it is seen that there has been organization between the new dura, the temporal muscle and the cortex, with contraction of tissue so that the lesion is confluent (A in Figure I).

The next dog was killed at the fourth month, and though the adhesions were not quite so tough, there was a general adherence over part of the cortex. The dog killed at five months showed general adherence of the dura, with evident contraction of the fibrous tissue, and discrete adhesions could be demonstrated only with difficulty (Figure I—III).

The Formation of Adhesions when Dry Membrane was Introduced to Cover the Deficiency.

In one dog, killed after nine days, there were moderately tough adhesions uniting the under surface of the temporal muscle with the cortex at all of the six areas injured. Some of these were pulled out by handling.

FIGURE II. Brain and adherent dura shown five months after operation where dry membrane was used. Details in text.

After two weeks (two dogs) adhesions were found to be general over the injured cortical area, but were filmy and easily pulled out of the cortex.

At five and a half weeks (two dogs), in one animal some adhesions were filmy and easily pulled out, though some were of moderate toughness. In the other the adhesions were moderately tough and one was vascularized.

After two and a half months the adhesions were widespread and tough and had contracted, but were toughest at the sites of injury.

At five months in two of three dogs the membrane (new dura) was fairly firmly adherent over the whole area (Figure II at A). In the third animal part of the area was firmly adherent and part showed discrete adhesions.

On the comparison of experiments in which muscle on the one hand and dry membrane on the other overlie the injured area, the difference in the appearance of the adhesions is greatly lessened after five weeks. At a later stage no essential difference can be detected.

FIGURE III. I, brain and dura with adhesions from a dog killed seven weeks after the introduction of boiled membrane; and II, from dog killed three and a half months after operation.

The Formation of Adhesions when Boiled Membrane was Used.

Penfield has pointed out further (1940) that unless amniotic membrane is boiled, adhesions are liable to be formed. In experimental studies on cats (Yi-cheng Chao, Storer Humphreys and Wilder Penfield, 1940) the membrane was always boiled.

Eight dogs were subjected to craniotomy and cerebral trauma as before, and the membrane was boiled for twenty minutes in distilled water before being applied. In four the membrane was used directly, and in the remainder

it was pressed out on a glass plate smeared with mineral oil as described in Penfield's original paper.

In the first group of experiments two dogs were killed at the seventh week and moderately tough adhesions were found (Figure III—I). These adhesions on handling broke away in places (Figure III—I at A). In another there were some filmy adhesions, especially at the periphery. After three and a half months it was found that the adhesions had thickened and become very tough, and were more firmly attached to the brain substance (Figure III—II).

In the second group of experiments in which mineral oil was used, two dogs killed at the seventh week showed moderately dense adhesions over the whole area of injured cortex. After three months extensive adhesions were observed. These were moderately dense, and some were contracted and vascularized. After four months the dura and cortex were closely bound together; though some of the adhesions could be pulled out fairly easily, some were dense and vascularized.

The Formation of Adhesions when Defatted Membrane was Used.

Since it was suggested that the development of adhesions with unboiled membranes (Penfield, 1940) might be due to fat which was said to be removed by boiling, dry defatted membrane was used in four further experiments.

After seven weeks moderately extensive and confluent adhesions were noted. After three and a half months the adhesions were tough and contracted. After five and a half months the adhesions were tougher and adhesion was closer between the cortex and the newly formed dura.

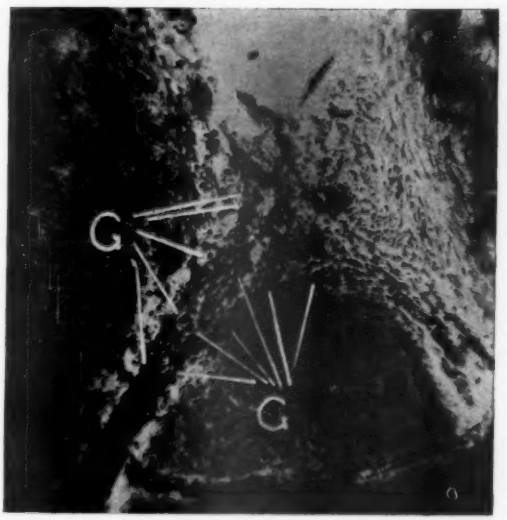

FIGURE IV. Section of cortex from dog killed nine days after the introduction of dry membrane stained with Sudan III. Details in text.

Frozen sections of the lesions were stained with Sudan III in experiments in which the membrane used had neither been boiled nor defatted. By the ninth day a well formed adhesion was present (Figure IV), but fat globules (G) were only to be observed below the line of the brain surface, and were probably derived from degeneration of nervous tissue. It is impossible to injure the brain surface without unmasking fat, and no fat was ever observed in the situation of the amniotic membrane itself.

Experiments on Guinea-Pigs.

In two guinea-pigs a slice of cortex six by five millimetres and two millimetres thick was removed. In one, dry amniotic membrane was placed over the dural defect, and it was found that seventeen days later the new dura was adherent over the region. In the other animal no membrane was used and adhesions developed to the same degree.

CONCLUSIONS.

1. Adhesions develop between the brain and reformed dura when the brain is injured and amnioplastin, dry, boiled or defatted, is used to cover the dural deficiency, but for the first seven weeks these are not so tough as those formed when no membrane is used.

2. After seven weeks there is little difference in the toughness of the adhesions formed, and in all cases there was increasing solidity of the adhesions with contraction.

3. There is no evidence that fat in the amniotic membrane can contribute to the reaction.

4. In one dog out of five in which no membrane was used, epilepsy developed, whereas in twenty-one experiments in which membrane was used, dry, boiled or defatted, epilepsy did not occur.

DISCUSSION.

The liability to develop epilepsy after head injuries, especially in cases of laceration of the brain with dural injury, has led to speculation as to its cause. Experimental work by Foerster (1926), Penfield (1927), Del Rio Hortega and Penfield (1927) and Penfield and Foerster (1930) has indicated the importance in the pathogenesis of epilepsy of the adhesions formed after head injury.

Penfield (1927) has shown that after cerebral laceration gross and progressive scarring occurs, but that when cerebral tissue is excised "there appears a fluid-filled space with a very small amount of gliosis about it . . . and without evidence of cicatricial pull upon the surrounding brain" (Foerster and Penfield, 1930). However, Yi-cheng Chao, Storer Humphreys and Wilder Penfield (1940) were evidently not completely satisfied, for they report that if the dura is deficient it is necessary to introduce a membrane (amnioplastin) to cover the defect and so prevent the formation of adhesions.

Penfield (1940) has further stated that it is necessary to boil the membrane if adhesions are to be avoided, and suggests that their formation with dry membrane may be due to fat in the membrane. We find that in the dog adhesions form whether the membrane is boiled or not, and further that specially stained preparations show fat only in the injured cortex.

It is possible that our results in dogs and similar failure to prevent adhesions in guinea-pigs may be explained by the assumption that human amniotic tissue, even when boiled, acts as a foreign irritant in these species. If this is so, it is surprising that Penfield and his colleagues obtained opposed results in experiments on cats.

It may be significant that in twenty-one dogs in which membrane was used, epilepsy was not observed, whereas in five in which corresponding damage was done without implantation of membrane, epilepsy developed in one animal. It must also be pointed out that the results of the use of human amnion in head injuries in man may not necessarily parallel those obtained in animals.

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Surgical Technique.

NOTES ON WAR SURGERY.[1]

EXPERIENCE in the battlefields has always resulted in improvement of the surgical treatment of wounds, and the present conflict has proved no exception to this rule. Some of these improvements are really more efficient methods of carrying out old established surgical principles, such as absolute rest and drainage for infected wounds. Chemotherapy is, however, a new feature, and, although not the answer to all infections, it has established for itself a definite place in the treatment of infected wounds.

Primary Treatment of Wounds.

After excision, all wounds should be left open and no attempt made to suture the wound, except in cases of gunshot wound of the skull, thorax, abdomen, and large superficial joints such as the knee joint.

After excision of wounds in muscular areas, no buried catgut sutures should be used; the only ligature material buried in the wound is that necessary to control hæmorrhage. The wounds should be packed with "Vaseline" gauze, which does not mean packing them tightly; it means filling loosely the space resulting from excision with "Vaseline", covering it with a few layers of gauze, and then applying plaster, if and when necessary.

In injuries of the limbs there are always those who strive for excision and primary suture. Primary suture should be forbidden in battle casualties. It is a frequent cause of bad results, necessitating in some cases amputation. There is always another day on which either to act or to regret; a secondary suture can be performed later. Primary suture, except in the areas indicated above, should not be practised.

It is essential to retain for observation for at least twenty-four hours any patient with a large wound which has been excised and whose limb has been encased in plaster to ensure that the plaster is not constricting to the limb and that the risk of reactionary hæmorrhage has been eliminated.

In all amputations in which flaps are fashioned, these must consist of skin and subcutaneous tissue only; the muscular tissue should be cut guillotine fashion at the point of section of the bone, and the flaps should be left unsutured or turned back for the first thirty-six to forty-eight hours; then if the stump is healthy a few (three or four) coapting sutures can be applied. The risk of gas gangrene appearing or spreading in an amputation stump is almost eliminated by this method, as gas gangrene spreads in the muscular layer. This is only carrying out the principle that the damaged muscle should be excised and the wound left unsutured. Flaps must not be sutured at the time of the original operation.

Compound Fractures of the Upper Extremity.

It has been shown in the recent activities that if compound fractures of the upper extremity are excised and dressed with "Vaseline" gauze, and if the extremity is placed in plaster in the correct position for the area injured, the results are satisfactory.

Except in special circumstances, care should be exercised to see that the volar slab of the plaster does not extend distally beyond the proximal transverse palmar crease. The volar plaster can be made longer and rolled back to this level, and this will adequately support the heads of the metacarpal bones. The dorsal slab extends as far distally as the heads of the metacarpal bones. Unless there is a contraindication, such as an injury to the radial nerve, the thumb should be in the position of function, in line with the shaft of the radius—that is, in line with the flexion movement of the index finger. The wrist joint should be extended approximately 30°. Volar plasters which extend beyond these levels and limit the movements of the metacarpo-phalangeal joints result in gross limitation of movement of these joints. This is a very serious disability.

This technique is not difficult except in the case of the humerus, where it is not easy to apply a spica if the patient is anæsthetized. In these cases patients travel well with the extremity bound to the thoracic wall, with the hand and wrist supported in plaster.

[1] Compiled from communications received from Army and Air Force medical officers serving in the Middle East theatre of war. Accepted for publication on December 17, 1941.

At the general hospital all these patients should be treated at the first dressing by the application of a plaster spica, if such has not already been applied. This is easily applied with the patient sitting up.

Compound Fractures of the Lower Extremity.

If any type of orthopædic table or sacral support is at hand, all such wounds should be excised completely, the foreign bodies removed, and the limb encased in plaster. In fractures of the leg the plaster should extend to the groin; in fractures of the femur a plaster spica is essential.

When fractures of the femur have been excised and treated on Thomas's knee splints with extension, the patients have not travelled well. If orthopædic rests are not available, the Thomas knee splint is, however, the only alternative and must be used.

Wounds Involving Large Joints.

Wounds involving large joints must be excised and the foreign bodies must be removed. If possible (and this is by no means always the case) the synovial membrane only should be closed; the open wound is then dressed with "Vaseline" and the limb encased in plaster.

In the case of the knee joint the limb so encased should be slung at the earliest opportunity by means of a Thomas knee splint. It can be slung during transport to the support bar attached to the end of the stretcher, or later by means of a Balkan frame.

Wounds of Face and Jaw.

Immobilization, wound *débridement* and adequate provision for drainage are the aims of primary treatment. Unnecessary delay increases misery and deterioration of general condition; it also aggravates sepsis.

Wound *débridement* should be thorough but conservative—that is, only foreign substances and devitalized tissue should be removed. Any small tissue flap may prove valuable to subsequent repair; care must be taken in the use of antiseptic about the eyes; saline solution is a good routine lavage agent.

These wounds are all potentially septic. Misguided attempts at primary repair under tension usually fail. This only causes more tissue loss and displacements, which must later be corrected with loss of time. Any established defect with tissue loss should be left.

Retraction is prevented by anchoring loose and displaced tissue flaps with a few catgut sutures in their normal positions. To the same end, it is a good practice to suture skin to mucous membrane about the periphery of defects involving the mouth or nasal cavities.

Provision for drainage must be made under any pocket or skin flap. Hæmatoma accumulation must be similarly prevented.

Wounds should not be tightly packed, but lightly covered with a few layers of "Vaseline" gauze (plenty of "Vaseline").

Dirt ingrained in wounds and abrasions as from blast injuries can be adequately removed at this stage by the use of gauze swabs and a stiff brush. If left, it can be removed later only by radical treatment or it must remain as unnecessary permanent disfigurement.

Bone fragments should not be removed from the site of fracture. Their preservation frequently obviates problems of non-union, shortening and bone grafting. Declared sequestra can easily be removed later.

Apart from removing broken particles of teeth as foreign bodies, the dental surgeon should be very conservative. Teeth, even if later removal is indicated, may be of extreme temporary value for jaw fixation or for preventing displacement of fragments.

Immobilization of bone fragments in as good position as possible is the prime consideration of early treatment.

Fracture of the Mandible.—Except for a few simple fractures of the mandible without displacement, any form of external bandage does not provide adequate temporary immobilization for comfort. Any bandage used must have an upward and forward pull—for example, the "barrel" bandage. The four-tailed bandage is to be condemned. If sufficient teeth are present, interdental wiring between three pairs of teeth by the "eyelet" method is the routine advised; this gives immobilization in good position against the opposing teeth.

With unsuitable disposition of teeth, "arch bars" wired one each to upper and lower teeth and fixed one to the other by wire or rubber bands may be more suited to some cases.

Edentulous patients may present difficulties. Use should be made of any unbroken dentures or a carefully made mould of dental compo, gutta percha or a vulcanite gunning type of splint. All must be supplemented by external bandage of the "barrel" type, with suitable head gear—rubber dam bandage attached to a head cap is satisfactory. No elaborate form of treatment should be carried out which in any way hinders early evacuation to the special unit.

Fracture of the Maxilla.—The same principle applies to fracture of the maxilla. Gross sagging displacements of the maxillæ are controlled by an inverted tray splint with external arms fixed to a head cap by traction as indicated.

Fracture of the Nasal and Upper Facial Bones.—In fracture of the nasal and upper facial bones disimpaction and early manipulation into correct positions are indicated. If the fractures are left this becomes more and more difficult. Retention apparatus is not usually required. Exit of nasal discharge, blood or cerebro-spinal fluid should not be impeded by plugging. No form of intranasal splinting should be used other than rubber tube with a free lumen.

Primary Treatment of Sucking Wounds of the Chest.

The experience of those surgeons working in forward areas is that the only efficient method of closure of sucking wounds of the chest is by suture.

Dressings and packing of the wound reinforced by adhesive plaster are not efficient. Wounds so treated often suck badly with change of position. The patient's condition will soon deteriorate if this occurs.

All sucking wounds of the chest must be closed by suture. This can be done at the forward areas without anæsthesia. Silkworm gut sutures are passed deeply into the tissues; they enter through the skin at least half an inch from the edge of the wound, emerge at a similar distance on the opposite side, and are then tied. The sutures must be passed deeply right down to the ribs or air will escape into the thoracic wall.

If the wound is a very large one, portion of a field dressing can be placed in the hole in the chest wall, and the sutures tied over it, the dressing being allowed to project considerably at each end.

Burns.

For practical purposes it is becoming common for those who deal with burns to classify them into those with partial skin loss or first and second degree, and those with complete skin loss or third degree. The older classification into six degrees has no practical significance.

A minor burn is defined as one of the first or second degree not exceeding 1% of the total body surface (that is, 28 square inches) unless it occurs on the hands, face, flexures or genitalia. All burns in these special areas of whatever degree, and those elsewhere exceeding 1% of the body surface, are considered to be major burns.

The Treatment of Burns.

Minor burns should be gently cleansed with saline solution and treated with one of the following coagulants.

(i) Painted with 2% gentian violet.

(ii) Painted with triple dye (brilliant green 1 in 400, gentian violet 1 in 400, neutral acriflavine 1 in 1,000, equal parts of each).

(iii) Sprayed with a mixture of 5% tannic acid and 10% silver nitrate.

(iv) Sprayed with 20% tannic acid.

(v) Covered with gentian dye jelly or "Tannafax".

Care should be taken to protect the resulting coagulum from external infection and any redness of the skin at the edges should be painted with gentian violet. The patient may be ambulant.

It will be realized that conditions in the field and in Royal Air Force units in England are not analogous. There are no burn centres in forward areas in the field. The time lag before the patient with a burn reaches a unit analogous to a burn centre is considerable—sometimes too long for tannic acid treatment to yield good results.

"Tannafax" as used in first aid posts has not been as successful as was hoped; uniform tanning does not occur and subsequent tanning is apt to fail. Patients with burns are being submitted to trial at certain first aid posts with initial saline or acriflavine dressings in order to allow the casualty clearing station thoroughly to clean and then to tan the burn. Meanwhile, coagulants are being used at first aid posts for all burnt areas except those on the hands, feet, face and genitalia. It is

realized that it is the time lag before first treatment under hospital conditions that matters. If the initial tanning fails because of infection, there is every indication to substitute saline baths and "Vaseline" dressings at the earliest opportunity, using improvised apparatus. The results obtained from this method of treatment, succeeded by early skin grafting, are a definite advance; they can be instituted only in base hospitals.

Major Burns without Shock.—Patients suffering from major burns without shock should be transferred forthwith whenever practicable to the nearest general hospital. Beyond the application of saline packs or the dye jelly to exposed parts such as the hands or face, no local treatment is to be used and the patient need not be undressed. In particular, tannic acid, silver nitrate and coagulant dyes should be avoided, as they may seriously compromise the final treatment at the general hospital; on no account must the hands be tanned. This cannot apply in forward sectors where tannic acid or gentian violet must be used for all areas except hands, face, feet and genitalia (where sterilized "Vaseline" will be used).

In the cleansing of the burnt areas and the removal of loose epidermis, the greatest gentleness is necessary and the part should be swabbed over with warm sterile saline solution only before coagulation. (Strong antiseptics, ether *et cetera* will only produce further tissue trauma.)

The onset of secondary shock in major burns is certain and often rapid, and it should be appreciated that irreparable damage may be done before the symptoms are easily recognized. Secondary shock is due to absorption of the products of protein destruction, and diminished blood volume (hæmoconcentration) from loss of serum either from the burnt areas or by œdema. Give reconstituted serum (a minimum of two bottles, and more if possible).

Major Burns with Severe Shock.—Shock with major burns is of paramount importance and must be given instant attention. In these cases the medical officer must treat the shock first and apply only first aid treatment to the burns consisting of the application of gentian violet jelly.

1. Keep the patient warm in bed, preferably beneath a shock cradle.
2. Raise the foot of the bed.
3. Give morphine freely, with due regard to previous dosage.
4. Give hot fluids freely by the mouth or rectum. Intravenous injection of saline solution is contraindicated as it has only a transient effect on the concentration of the blood and rapidly passes out into the tissues.
5. Oxygen may be given by means of the ordinary service mask or through an anæsthetic mask. The B.L.B. mask may be used where available. High concentrations of oxygen up to 100% are advisable.
6. Reconstituted dried human serum must be given intravenously in all cases of shock as soon as a supply becomes available. Alternatively, wet serum or plasma may be used when available.

For approximate calculation of the decrease of plasma volume in shocked patients not suffering from hæmorrhage, D. A. K. Black in the *British Medical Journal*, November 23, 1940, has shown that one is justified in assuming an initial hæmoglobin percentage of 100 and a blood volume of five litres, of which three litres are plasma. The increased hæmoglobin value observed bears the same ratio to the initial value as the initial value for blood volume does to the new blood volume, since the red cell volume remains unchanged. From this, Table I was compiled.

TABLE I.

Hæmoglobin Percentage. (Haldane.)	Blood Volume. (Litres.)	Plasma Volume. (Litres.)	Estimated Deficit in Plasma Volume. (Cubic Centimetres.)
100	5·0	3·0	—
105	4·75	2·75	250
110	4·55	2·55	450
115	4·35	2·35	650
120	4·15	2·15	850
125	4·0	2·0	1,000
130	3·85	1·85	1,150
135	3·7	1·7	1,300
140	3·55	1·55	1,450
145	3·45	1·45	1,550
150	3·35	1·35	1,650

From Table I can be calculated the amount of plasma or serum required to reconstitute the initial blood volume.

The Treatment of Burned Areas.—In almost all cases the treatment of burned areas will be undertaken in the general hospitals. Table II shows the technique at present in use.

TABLE II.

Area.	First Degree, Second Degree, with or Without Shock.	Mixed Types, Second and Third Degrees.	Third Degree.
Trunk and extremities (excluding hands), particularly extensive burns.	*Minor burns:* Dye jelly. "Tannafax." Tannic acid dyes. *Major burns:* 1. Tannic acid, 20%. 2. Tannic acid, 5%, and silver nitrate, 10%. 3. Gentian violet, 2%. 4. Triple dye.	*With shock:* Tannic acid. Silver nitrate. Aniline dyes. *Without shock:* Saline bath.	*Local small areas:* Excision and graft. *Extensive areas:* Saline preparation of granulating surface and early grafts. *Tulle gras* technique.[1]
Face	Saline packs throughout or *tulle gras* and "Vaseline" followed in six to eight days by gentian violet or triple dye.	——	Saline packs till ready for grafts.
Hands	Saline baths throughout or *tulle gras* and "Vaseline" followed in six to eight days by gentian violet or triple dye. Early movement particularly in saline solution. Never use tannic acid.	——	Saline baths, *tulle gras* technique. Early movements. Early grafts.
Flexures and genitalia.	Saline packs or hot baths. Gentian violet or triple dye. *Tulle gras* and "Vaseline".	——	Saline packs or baths. Early grafts.

[1] "*Tulle gras*", originally a French preparation, may be prepared in the following way. Curtain net, with a mesh of two millimetres, is cut into pieces nine centimetres square. These are placed in a box of slightly larger size with grease-proof paper between each square of material. The box is then filled with the following mixture: soft paraffin, 96 grammes; balsam of Peru, 2 grammes; halibut oil, 2 grammes. Sufficient to impregnate and cover the material completely after sterilization.

Sepsis under Coagulum.—If sepsis is present under a coagulum the coagulum and underlying sloughs must be immediately removed under anæsthesia or by means of saline packs or baths. *Tulle gras* technique is used with local saline packs.

Tannic Acid on Hands.—If tannic acid is present on the hands, its immediate removal with 3% salt solution is necessary. Continue with saline baths. Early movement of fingers must be undertaken.

Tulle Gras Technique.—After saline baths, strips of *tulle gras* are laid over the burned surfaces without allowing them to dry. Wet saline packs are then laid on the *tulle gras* and are changed every two hours without being allowed to dry. The *tulle gras* remains on until the next bath, when it floats off in the saline solution. In this way dressings are never allowed to stick and can be made completely painless.

Phosphorus Burns.—Medical officers may be called upon to give treatment for phosphorus burns resulting from accidents met with in dealing with self-igniting phosphorus grenades *et cetera*. It is recommended that these burns should be dealt with on the following lines. Immerse the affected part in water or, if sufficient water is not available, apply a thick pad soaked in water. Particles of phosphorus embedded in the skin should be removed under the water by means of gauze held in forceps. No oils or greasy dressings should be used. Wash with dilute alkaline solution—for example, soda bicarbonate or sodium carbonate, two drachms to a pint of water. Remove all traces of phosphorus by washing with 1% solution of copper sulphate. Remove resultant dark deposit of copper phosphide and wash with a mild antiseptic—for example, boric acid. Then dress as for ordinary burns.

Blast Injuries.

It is difficult to differentiate between pulmonary concussion the result of blast and poisoning from nitrous fumes. Fortunately this is of no great significance, since indications for treatment in both cases are practically identical. It is important to bear in mind the possibility of multiple lesions in conditions resulting from high explosives. In the initial stages of injuries of this nature anoxia dominates the clinical picture, and the only way of combating this is by the adequate administration of oxygen controlled by accurate observations of the mental state, the pulse rate and the presence or absence of cyanosis.

These cases require oxygen flow of seven to eight litres per minute continuously on the first day and during interrupted periods dictated by the clinical state of the patients on the second day. The restless irritable condition of some of these patients makes necessary the use of morphine before oxygen can be effectively administered. An interesting point is the slight effect of oxygen in diminishing the ventilation rate of the lungs. As in the case of left heart failure, this is probably due to the fact that the dyspnœa is mainly reflex in origin from the congestion of the pulmonary bed and is not due to changes in the carbon dioxide or oxygen tensions of the blood.

The very real risk of a superimposed bacterial infection must be constantly borne in mind in the treatment of these injuries. The physical exhaustion and undernutrition of men on active service, in conjunction with the above lesions, would lower the resistance and favour the spread of latent or mild infections of the upper respiratory tract into the depths of the lungs. This reasoning was borne out by experience with recent casualties. In many cases on the third day following the original injury there was clinical evidence of a pulmonary infection which responded to sulphapyridine therapy.

The importance of enjoining prolonged rest in bed in the more severe cases of this type cannot be over-emphasized. Even the mild physical exertion associated with an X-ray examination may be enough to precipitate an exacerbation or relapse of the lung condition.

Summary.

These notes are by no means a concise account of war surgery, but are the comments made by experienced surgeons following their experience so far in the present war. Regarded in this light, it is hoped that they will be of interest and of some help to those interested in this subject.

Surgery in Other Countries.

[In this column will be published short résumés of articles likely to be of practical value from Journals published in other countries and not readily accessible to surgeons in Australia and New Zealand.]

DIFFERENTIAL DIAGNOSIS IN GASTRIC HÆMORRHAGE.

Erik Ask-Upmark (Lund): *"Zur Differentialdiagnostik der Magenblutungen"*, *Acta Chirurgica Scandinavica*, Volume lxxxiv, June, 1940, page 30.

THE cause of a massive gastric hæmorrhage, evidenced by hæmatemesis and melena and associated with acute anæmia, may lie in a local lesion in the upper part of the digestive tract; in circulatory disturbance in the portal venous system, such as cirrhosis of the liver or thrombosis of the portal or splenic veins; or thirdly it may be only a local expression of a general disease carrying a hæmorrhagic tendency. The distinction is of course ephemeral, since on the one hand an ulcer may be essentially a local expression of a general disease and, on the other hand, the gastric bleeding in such a condition as malignant nephrosclerosis is the result of local change differently located. In practice the last-named cause is seldom difficult to diagnose. Both the history and the clinical examination indicate a severe general disease with a hæmorrhagic tendency; and it is only necessary to stress the point that a high non-protein nitrogen content in the blood does not necessarily mean severe renal damage. It may be due solely to the presence of quantities of blood in the alimentary canal.

The possibility of gastric carcinoma must always be kept in mind, especially in the examination of patients of "carcinoma age" whose symptoms are of relatively short duration, and who are predominantly dyspeptic. In Ask-Upmark's clinic it is the rule to undertake a radiological examination early, without waiting for the bleeding to cease. Although the possibility must be kept in mind, it may be conceded that gastric carcinoma does not often manifest itself by massive hæmorrhage.

Portal stasis does more frequently come into consideration. It often happens that a patient will be admitted to hospital in such a condition that life saving must supersede all investigations, and when a radiological examination is made no ulcer can be demonstrated. The conclusion may then be reached that the bleeding is caused by gastritis or by an ulcer which has healed in the meantime, or that the examination has been in some way faulty. It is in these cases that the possibility of portal stasis should be taken into account in the differential diagnosis. Such bleeding may have been due to hepatic cirrhosis with œsophageal varices, or to splenic thrombosis.

Thrombosis of the splenic vein is comparatively rare, but is more frequent in men than in women, and occurs mostly in young people. Its cardinal characteristic is splenic enlargement without any signs of hepatic cirrhosis, but with a tendency to gastric hæmorrhage. The diagnosis is not made easier by the fact that the spleen may decrease rapidly in size simultaneously with the onset of bleeding, and this particularly in young folk with contractile spleens. For this reason palpation of the spleen should be undertaken in such patients, not only at the first, but at all subsequent examinations.

Cirrhosis of the liver is more common, and it is in these cases that experience demonstrates the difficulty of differential diagnosis. The history can sometimes give a lead, by revealing in an alcoholic patient the presence of the typical dyspepsia; but against this must be set the fact that many cases of hepatic cirrhosis are due to causes other than alcoholism, while alcoholics can and do suffer from gastritis and gastric ulcers without cirrhosis. Further, cirrhosis can cause symptoms very closely resembling those of ulcer, including the pain after meals and the night pains. Clinical examination may help. A hard palpable "ulcer resistance" in the stomach region, indistinguishable from a carcinoma, is the one alternative, a palpable altered liver is the other. Further signs of portal stasis, such as ascites, increased prominence of the veins of the abdominal wall, splenomegaly and hæmorrhoids, may be present. In addition, the search for œsophageal varices by X-ray examination is useful, for though their absence means nothing, the finding of them is conclusive.

In those cases—not a few—in which the diagnosis is doubtful, help may be sought from the tests for liver function. Unfortunately the margin of functional efficiency of the liver is so wide, and its actual functions are so manifold, that a negative result from any of the usual tests will not exclude liver damage. And severe damage caused to the liver by cirrhosis can be so far compensated for that the result of any test, whether directed to the blood or to the digestive canal, may be entirely misleading, whatever the state of the liver. For example, galactose absorbed may by-pass the liver through the portal anastomoses, which act somewhat similarly to an Eck's fistula. And, on the other hand, signs of depressed hepatic function can sometimes be discovered in cases of pure gastric or duodenal ulcer. And finally the same patient may suffer from both cirrhosis and ulcer. The sole test for hepatic function which does assist in the diagnosis is the Takata-Ara test, which always gives negative results in ulcer cases. In general, in attempts to make this diagnosis clinical methods, when all are used, are more helpful than the laboratory.

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Reviews.

Surgery of the Heart. By E. S. J. KING, M.D., M.S., D.Sc., F.R.C.S., F.R.A.C.S.; 1941. London: Edward Arnold and Company. Medium 8vo, pp. 738, with 268 illustrations, including 4 colour plates. Price: 50s. net.

THIS monograph could not have been published at a more opportune time, for it meets a need, and every surgeon on active service will welcome it. Warfare on a large scale has always led to advances in the science and art of traumatic surgery. It cannot be questioned that the present conflict will have a similar influence on the traumatic surgery of the heart. Surgeons at the present time are becoming "heart minded". Evidence of this is the prominent place given to many aspects of the surgery of the heart in the programme of the Thirty-First Clinical Congress of the American College of Surgeons at Boston last November. Major King's work is in substance the Jacksonian Prize Essay of the Royal College of Surgeons of England for the year 1938. This gifted surgeon's success is the third occasion on which he has achieved the distinction. It would seem that he has only to enter for the Jacksonian Prize to win the coveted "blue riband" of the College. It is fortunate for the progress of surgery that he is serving overseas in a unit in which he has already seized the occasion to add to the knowledge of thoracic and cardiac surgery. The first section of his book is devoted to a concise account of the development, the anatomy, the physiology and the pathology of the heart. It also includes the radiological and electrocardiographical examination of the

heart. The second and much larger section deals with the surgical approach to heart diseases and their general operative treatment. In order follow accounts of diseases of the myocardium and coronary vessels, of the endocardium and of the pericardium and great vessels. The surgical treatment which is applicable is described. The author quotes Sherman's epigram: "The road to the heart is only two or three centimetres in a direct line, but it has taken surgery nearly 2,400 years to travel it." That progress has been rapid since Billroth wrote nearly fifty years ago: "The surgeon who should attempt to suture a wound of the heart would lose the respect of his colleagues." Major King is a staunch believer in operative efforts being made to restore the action of the heart after cardiac arrest, and gives good reasons for his faith. He insists that the anatomical and physiological principles underlying methods of technique demand close study. While the surface surgery of the heart is well substantiated, the author holds that there are "many indications that intra-cardiac surgery is not far away". The author's account of the various operative procedures, their indications and their limitations is characterized by a wise critical faculty based on personal experience and research. In his attitude towards cardiac surgery he is an optimist—and rightly so. The book is attractively written, and the illustrations excellently illuminate the text.

We have no hesitation in urging that the work should find a place in the library of every surgeon and in that of every medical unit on active service. Nor can any physician afford to ignore it.

Surgery of Modern Warfare. Edited by H. BAILEY, F.R.C.S.; Part V; 1941. Edinburgh: E. and S. Livingstone. Super royal 8vo, pp. 235, with 144 illustrations. Price: 17s. 6d. net.

PART V completes "The Surgery of Modern Warfare". The treatment of injuries to the ear is concluded and V. E. Negus contributes another chapter on wounds of the air passages and air sinuses. An excellent section on wounds of the central nervous system comprises a chapter by Dott on those of the brain and skull, two chapters on the spine and spinal cord by Cohen and Lambert Rogers, and a very informative statement by Ogier Ward on the management of the bladder in cases of spinal injuries. In this chapter Ward stresses the view that suprapubic cystostomy is under average conditions the best method of treatment for retention of urine due to spinal paralysis.

The rest of the volume consists mainly of chapters on the administration of various medical services, and at the present time Chapters 56 and 57 on "Hospital Organisation in the Emergency Medical Service" and "Organisation of a First-Aid Post" are of especial interest to those in Australia who may be called upon to undertake such work. That difficulties in staffing first-aid posts with volunteers have been encountered is obvious from the remark that the depot supervisor, to whom, it has been found, the medical man must delegate responsibility, should be "as it were adjutant quarter-master and sergeant-major rolled into one", and that he should be a man possessed of the "tact of an ambassador, the hide of a rhinoceros and the patience of Job", because he must continually settle disputes and obviate friction in a large staff over whom he has no authority beyond their willingness to serve.

In an appendix compiled by the editor, recent references are summarized. The volume has been produced in the same style as the preceeding volumes, the references include many to articles published in 1941, and the fact that the same high standard has been maintained despite all obstacles is a matter for which the editor and the publishers deserve the highest praise.